enerSave

For Industry
and Commerce

GUIDEBOOK/INDEX 1

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Office of Energy Conservation
Bureau de la conservation de l'énergie

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Guide Book and Index

Introduction:

Designed as the hub of the OEC industrial handbook series, the introductory booklet deals with the general rationale for energy conservation in today's economic climate and attempts to deal with some of the necessary definitions and concepts common to each of the subject areas.

Distributed as a companion in response to requests for one or more of the other booklets in the series, the guidebook should function as the conduit which takes the interested reader to the specific, required case history or text material in other booklets or to one of a myriad of outside sources of information or assistance.

Energy Conservation

"There's nothing new under the sun."

It's a phrase that is often heard and one which, depending on how it's applied, has more than a grain of truth in it.

In applying the concept to the practice of energy conservation, for example, the statement cannot be taken literally. There have been, and continue to be quite a number of new technological tools developed which if used correctly can help make the job of conserving energy a less onerous one.

But it is true to say that many of the techniques and equipment which should be applied to industrial situations to reduce energy wastage have been around for quite a long time. Subject to minor modifications, the concepts really haven't changed that much.

What has changed markedly is the economic climate in which industry now operates. Times are generally tougher. Competition, both domestic and international, abounds. And in many cases, companies are being forced to find means to reduce costs and overheads just to keep "the bottom line" in relatively healthy shape. Energy conservation is just one avenue being explored by cost conscious companies.

Perhaps more importantly, the cost of energy as a fuel and feedstock to industry has increased dramatically over the past few years. Energy conservation projects that were brought forward over the years by engineering departments in companies all over Canada — only to be neglected — are now being re-evaluated in the light of today's energy economics.

In fact, many companies are taking the enlightened step of evaluating energy conservation projects in the light of tomorrow's energy economics. Because if one thing is certain in our ever changing industrial environment, it is that greater escalation in the cost of power and fuel can be expected. Not solely due to the actions of international commodity cartels such as OPEC — but more correctly as a result of the increasing costs of providing energy, either from more remote conventional sources or through expensive new technology currently in various stages of development.

"Nothing ventured . . . nothing gained".

There's another phrase that is often heard. But this time it's one which can be applied directly and without any apprehension to the energy conservation situation.

In normal parlance, it has come to mean that a company can expect to make no return if it is unwilling to take certain calculated and manageable risks with capital.

This is the situation which faces companies evaluating possible capital expenditures on energy conservation programs — but with one major exception. "Risk", as such, is minimal.

A company can carry out a penetrating program of market research before spending the money to manufacture and launch a new product. But it really doesn't know for sure, until the product is put in front of the public in a buying situation, whether or not it will sell. And, depending on the nature of the product an the market, how long the product will sell — and continue to generate revenue — are at the whim of technological change, trends, styles or fads.

In fact, there are very few situations which offer

industrial management both a substantial return on capital investment and the certainty that the return will be forthcoming.

By and large, energy conservation programs can do just that. And, in many cases, toss into the bargain better employee morale and productivity.

The challenge, then, is to make those responsible for untying the purse strings aware that energy conservation is an extremely attractive investment vehicle. One that offers a specified and largely guaranteed rate of return and at the same time improves the company's cost leverage and makes it more competitive in the marketplace.

Taking it from the opposite viewpoint, the company that doesn't actively pursue cost cutting and dollar savings from the standpoint of an energy conserver is going to be in a greatly disadvantaged position with its competitors, if those competitors are attentive and opportunistic about potential energy savings.

Most top management people are aware of the "macro" situation as it pertains to energy. They know that the country is running short of energy — particularly energy derived from hydrocarbons, and that for the national good, an effort must be made to conserve energy in all forms.

To some extent, then, top management is pre-sold. But they are also pre-sold on the need for growth in revenue, and infinite requests are generally made at budget time for a finite amount of money available for capital projects of any kind. As a result, energy conservation programs have to be presented in the same light as any other investment opportunity. That is, they need to be thoroughly researched and documented and provide the most sophisticated analysis of return on investment that can be mustered up.

In short, subject to some tactical constraints, the plant manager or energy conservation specialist should be able to make top management "an offer they can't refuse". Or, at least one which is, on balance, at least as attractive as any other investment option available.

Start with "quick fix" and other programs that don't require a capital investment. Choose initial energy conservation projects not only for their strict energy saving opportunities, but for their visibility to both employees and management. Build up a track record. In short, do everything to assure that energy conservation is seen as a solid, investment opportunity — and not a passing fancy that will not be a priority five years from now.

But remember plant management or others responsible have to be willing to "go to bat" for the programs . . . they have to have the courage of their convictions . . . and most importantly, they have to be willing to "ask for the sale" — to make a strong case for the funds needed to put in motion programs that will ultimately bring a good return to the company in reduced energy usage and dollar savings.

In essence, that is the purpose of this initial series of handbooks: to put a basic threshold of energy conservation information in front of a large population of Canadian industrial managers who are now responsible for, or who will in the future take responsibility for, energy conservation within their respective companies.

The booklets are not the definitive source of information on any one of the broad range of subjects covered. But they are, hopefully, a useful source of explanatory, reference and case history material — and above all, a source of *ideas*.

They will not, nor are they intended to, allow Canadian companies to carry out all energy conservation programs without the help of consultants, contractors and suppliers' representatives. Nor do they offer pat solutions to complicated problems.

But they do offer ideas which can be intelligently applied to most industrial situations, bearing in mind the trade-offs that exist and the multitude of variables that must be taken into account.

Each plant is different in some way. And as a result, certain methods may or may not be applicable — either directly or indirectly. But it is hoped that the booklets will provide enough information to encourage industry to follow certain avenues of energy conservation by providing relevant information.

This introductory booklet contains general refrence material not as specifically related to any particular subject — along with a discussion of other topics which pertain generally to energy conservation. Sections include: implementing a successful program; how to conduct an energy audit; degree days; financial analyses of energy

conservation; government assistance; metric conversion and tables; and helpful terms and formulae. But perhaps the most important function of the Guidebook is to provide a cross-referenced index for the full series of booklets.

Since the range of topics is great, it was difficult to stick to a standard format and organization for all of the booklets. For the most part, each contains a general introductory section, case history examples, and a list of short suggestions. But the booklet on employee motivation, for example, does not contain any specific case histories.

Some of the topics overlap — the booklets on heating, and combustion control, for instance. Consult the index in the Guidebook in all cases like this to ensure that you have all the appropriate references.

How the booklets are used will depend on the requirements of the reader, but it is hoped that they will, in fact, be used regularly. And not put on a shelf with stacks of other "reference" material.

A list of titles in this series, and ordering instructions, are at the back of the book.

A word on units and costs.

For the sake of consistency, all amounts are given in Imperial units, unless otherwise specified. A metric conversion chart for all units is provided in all manuals.

A special *caveat* should also be stated regarding dollar figures, particularly as used in the case histories. Energy costs have been re-cast to reflect a single unit cost for each commodity. The representative unit costs were provided by National Utility Services as a reasonable basis for comparison considering the regional disparities of Canadian energy prices.

While most capital costs are stated in current, or at least recent dollars, a few are more than five years old — and *no attempt has been made to escalate capital or operating costs to a constant dollar base*. Readers should, therefore, accept numbers as representing an "order of magnitude" and substitute their own figures when attempting to apply formula calculations to their plant situation.

Implementing a successful program

This section of the Guidebook describes and illustrates the actions necessary to initiate and implement a successful energy program. It may be used as a guide to design your own program, tailored to your company's requirements and capabilities. Note that whether a company is large or small, the four important steps in the energy conservationprogram are:

- Top management commitment and goals
- Survey energy uses
- Take action to save energy
- Develop continuing effort

The essential elements common to successful programs are discussed here, as are appropriate procedures to follow. The booklet on Employee Motivation provides additional information on the subjects of management commitment, publicity and involving employees, while the section in this book dealing with energy audits amplifies the subject of surveying energy uses and losses.

Program outline

I. Top management commitment.

A. Inform line supervisors of:

1. The economic reasons for the need to conserve energy.
2. Their responsibility for implementing energy saving actions in the areas of their accountability.

B. Establish a committee having the responsibility for formulating and conducting an energy conservation program and consisting of:

1. Representatives from each department in the plant.
2. A co-ordinator appointed by and reporting to management.

NOTE: In smaller organizations, the manager and his staff may conduct energy conservation activities as part of their management duties.

C. Provide the committee with guidelines as to what is expected of them:

1. Plan and participate in energy saving surveys.
2. Develop uniform record keeping, reporting, and energy accounting.
3. Research and develop ideas on ways to save energy.
4. Communicate these ideas and suggestions.
5. Suggest tough, but achievable, goals for energy saving.
6. Develop ideas and plans for enlisting employee support and participation.
7. Plan and conduct a continuing program of activities to stimulate interest in energy conservation.

D. Set goals in energy saving:

1. A preliminary goal at the start of the program.
2. Later, a revised goal based on savings potential estimated from results of surveys.

E. Employ external assistance in surveying the plant and making recommendations, if necessary.

F. Communicate periodically to employees regarding management's emphasis on energy conservation action and report on progress.

II. Survey energy uses and losses.

A. Conduct first survey aimed at identifying energy wastes that can be corrected by maintenance or operations actions, for example:

1. Leaks of steam and other utilities.
2. Furnace burners out of adjustment.
3. Repair or add insulation.
4. Equipment running when not needed.
5. Inefficient space utilization.

B. Survey to determine where additional instruments for measurement of energy flow are needed and whether there is economic justification for the cost of their installation.

C. Develop an energy balance on each process to define in detail:

1. Energy input as raw materials and utilities.
2. Energy consumed in waste disposal.
3. Energy credit for by-products.
4. Net energy charged to the main product.
5. Energy dissipated or wasted.

NOTE: Energy equivalents will need to be developed for all raw materials, fuels, and utilities, etc., in order that all energy can be expressed on the common basis of Btu's.

D. Analyze all process energy balances in depth:

1. Can waste heat be recovered to generate steam or to heat water or a raw material?
2. Can a process step be eliminated or modified in some way to reduce energy use?
3. Can an alternate raw material with lower energy content be used?
4. Is there a way to improve yield?
5. Is there justification for:
   a. Replacing old equipment with new equipment requiring less energy?
   b. Replacing an obsolete, inefficient process plant with a whole new and different process using less energy?

E. Conduct weekend and night surveys periodically.

F. Plan surveys on specific systems and equipment, such as:

1. Steam system.
2. Compressed air system.
3. Electric motors.
4. Natural gas lines.
5. Heating and air conditioning system.
6. Other electrical usage.

III. Implement energy conservation actions.

A. Correct energy wastes identified in the first survey by taking the necessary maintenance or operation actions; do the simple things first.

B. List all energy conservation projects evolving from energy balance analyses, surveys, etc. Evaluate and select projects for implementation:

1. Calculate annual energy savings for each project.
2. Project future energy costs and calculate annual dollar savings.
3. Estimate project capital or expense cost.

4. Evaluate investment merit of projects using measures such as return on investment, etc.
5. Assign priorities to projects based on investment merit.
6. Select conservation projects for implementation and request capital authorization.
7. Implement authorized projects.

C. Review design of all capital projects, such as new plants, expansions, buildings, etc., to assure that efficient utilization of energy is incorporated in the design.

NOTE: Include consideration of energy availability in new equipment and plant decisions.

IV. Develop continuing energy conservation efforts.

A. Measure results:

1. Chart energy use per unit of production by department.
2. Chart energy use per unit of production for the whole plant.
3. Monitor and analyze charts of Btu per unit of product, taking into consideration effects of complicating variables, such as outdoor ambient air temperature, level of production, product mix, etc.
   a. Compare Btu/product unit with past performance and theortical Btu/product unit.
   b. Observe the impact of energy saving actions and project implementation on decreasing the Btu/unit of product.
   c. Investigate, identify, and correct the cause for increases that may occur in Btu/unit of product, if feasible.

B. Continue energy conservation committee activities.

1. Hold periodic meetings.
2. Each committee member is the communications link between the committee and the department supervisors represented.
3. Periodically update energy saving project lists.
4. Plan and participate in energy saving surveys.
5. Communicate energy conservation techniques.
6. Plan and conduct a continuing program of activities and communication to keep up interest in energy conservation.
7. Develop cooperation with community organizations in promoting energy conservation.

C. Involve employees.

1. Service on energy conservation committee.
2. Energy conservation training course.
3. Handbook on energy conservation.
4. Suggestion awards plan.
5. Recognition for energy saving achievements.
6. Technical talks on lighting, insulation, steam traps, and other subjects.
7. Posters, decals, stickers.
8. Publicity in plant news, bulletins.
9. Publicity in news media.
10. Letters on conservation to homes.
11. Talks to local organizations.

D. Evaluate program.

1. Review progress in energy saving.
2. Evaluate original goals.
3. Consider program modifications.
4. Revise goals, as necessary.

Elements of an energy audit

Many businessmen today are becoming aware that auditing their energy consumption is as important to the health of their business as keeping track of their financial performance.

Like financial audits, energy audits identify not only the amount spent, but more importantly, exactly where and how resources are expended. Energy auditing does not, however, necessarily provide the final solution to the problem, rather, it indicates where the greatest potential for conservation lies and, therefore, where the

major portion of any conservation effort should be. Also, it provides efficiencies of operations, and for creating meaningful Return-on-Investment analysis.

Some provinces currently operate "energy buses" which will help perform energy audits, using a computer, on request. Other provinces are considering the concept. The questionnaire used in an audit by Ontario's energy bus is appended. However, if an energy bus is not available, the following information will be of assistance in carrying out an audit program. And the charts and appendices at the end of this section should prove useful in providing the documentation needed for such an undertaking.

How much work is involved?

Suppose yours is a small operation, maybe just a couple of machines, a small boiler, and a few employees. Energy audits need not be complicated. For simple systems, an energy audit may be performed in just a few hours by a plant engineer or a maintenance foreman. The results will point to areas where energy waste can be reduced or even eliminated.

Audit complexity and the level of detail required depend on the complexity of the process itself and the purpose to which the information will be put. A small plastics injection molding operation, for example, could involve only a single raw material, along with inputs of electric power and water. A rough energy analysis might show that the heat contained in the water used to cool the molds can be utilized at some point in the building to save on the gas bill. Because energy represents a small portion of the cost of this production process, only a one-shot look at the energy utilization might be warranted.

On the other hand, a petrochemical manufacturing plant represents an extremely complex system. Its many inputs of raw material and a multiplicity of products require careful engineering analysis.

So the questions "How complex does an audit need to be? and "How much work is involved?" have as many answers as there are different industrial operations and people who manage them.

How do you proceed?

There are four levels of energy audit procedures. Starting with the simplest (and least expensive), they are:

1. the historical audit
2. the diagnostic energy audit
3. the periodic energy audit
4. the continuous energy audit

As each level is completed, it should become fairly obvious whether you should proceed to the next level, or some portion of it. Many small companies may obtain full benefit from just the first or, perhaps, the first two levels. But, as industrial processes grow more and more complex, the third and fourth levels should be completed.

In any case, everyone whose total energy bill exceeds either 5% of their gross expenses or $1,000 per month should give serious thought to performing at least Step 1, the historical audit.

Step 1 — The Historical Audit.

Normally, no technical expertise is required for the historical audit, and results can often be extremely valuable in pointing the way toward a closer look at individual elements of the plant.

The historical audit procedure makes use of available accounting and production records. A careful look should be taken at the total energy consumed per unit of plant output over the past several years, and a record displaying these figures should be created.

Appendix C provides you with a convenient form for the collection of energy use data from past utility and production records. Those entries dealing directly with fuels are uncomplicated, and may be obtained directly from fuel bills. Some typical "heating values" you can use in filling out the charts are:

Natural Gas — 1,000 Btu/cu. ft.
Fuel Oil (No. 2) — 166,000 Btu/gal.
Fuel Oil (No. 6) — 180,000 Btu/gal.
Coal —
Bituminous — 14,000 Btu/lb.
Sub-bituminous — 10,500 Btu/lb.
Lignite — 7,500 Btu/lb.

More precise values can be obtained from fuel suppliers; they are often shown directly on fuel bills.

You will note that in Appendix C, electrical energy use can be left in terms of megawatt-hours instead of being converted to Btu's. If you generate your own electricity, Mwh's would not be shown; in their place, you would list the Btu value of the fuel used for generation.

Depending upon the nature of the operation, the term, "Units of Production", may or may not be obvious. The production rate of an oil refinery, for example, corresponds directly to the number of barrels of crude oil processed in a given period; and therefore, the unit of production could be "barrels of oil". Suppose, however, one is analyzing a precision machine shop operation, in which the majority of the energy consumption is associated with the operation of the building and various machining equipment. It is unlikely that this shop's products would vary widely in complexity, volume, and amount of energy used. Thus, some judgement is required to select an appropriate measure — for the machine shop or other operation with widely divergent outputs, man hours or dollar value of production may be an appropriate "unit".

The ultimate quantity to be determined is the energy use per unit of production (in Mwh and Btu/unit). These quantities are much better indicators of energy utilization performance than are the gross quantities of energy consumed. Once an "overall energy efficiency" has been determined, it may be used as a baseline from which to compare improvements made through operational or equipment modifications. Also, a review of the data may reveal certain facts that will lead to an immediate conclusion about some piece of equipment. But some caution should be exercised since production rates vary from month to month, and since these variations can have a large effect on the ratio of energy expended per unit produced, it would be inappropriate to compare ratios during a high production period with those during low production.

For example, a review of your records might reveal that when a new machine was added to the production line, the average energy consumption per unit of production dropped the following month. This would suggest a closer look at the energy consumption for the new machine compared with the older units. A cost tradeoff analysis could be worked out on the basis of current and anticipated fuel and electricity prices. This analysis should enable you to determine when it might be economical to replace some of the older equipment.

Step 2 — The Diagnostic Energy Audit.

Although the example given would lead to a conclusion on a specific piece of equipment, normally a historical audit only gives an indication of the *total* facility's energy efficiency. Therefore, a diagnostic energy audit would normally be required to isolate the energy flows for specific components or processes within your plant. Thus, the diagnostic audit is a technical analysis of individual components, or groups of components or processes. It is based on existing or estimated operational data, and is used to identify the amount of energy expended either in a certain machine, portion of a process, or a total process.

Such a determination is made by performing a "mass balance", which accounts for the flow of all materials involved; and an "energy balance", which tracks the flows and transformation of energy within that part of the system being measured. In both cases, the basic physical principle is this; neither mass nor energy is destroyed in the process. Whatever goes in must either come out or be stored within the system. With this concept applied to any machine or system, it becomes possible to obtain a fix on the ways energy is usefully employed.

The two diagrams provide a pictorial representation of the basic concepts of energy and mass balances. In each drawing the arrows depict the flow of either mass or energy. Appropriate measurements or estimates of these flows will begin to provide a clear picture of what happens within the equipment. Determining the values for the mass and energy balances may require direct measurements or may require computation.

When direct measurements of mass or energy flows are not taken, information on machine time-on to time-off ratio is important. One simple way to obtain this data is to use an electric clock placed in parallel with the machine for a predetermined period of time, such as one day or one production shift. The elapsed time shown on the clock divided by the total time period gives the fraction of time the machine is in operation.

Obviously, when processes other than those

listed are involved, other formulas are available to provide the necessary quantification of energy flows. You may need to seek some additional technical help from competent engineers; however, much help can often be obtained from equipment manufacturers, utility representatives, and various technical reference books available in libraries.

We've talked about the diagnostic energy audit to enable the reader to understand the desired result. You may decide to call in a consultant to perform this effort, but, whether you do this or not, the first steps can and should be done by you.

The information needed to carry out a diagnostic, or higher level, energy audit includes both overall plant system data and detailed specifications on each energy-using component. You should begin by assembling a set of plant layouts showing the location and interconnection of all equipment. In particular, it is important to show all fuel, electrical, air, and steam lines. Water piping need not be shown unless water is used as a coolant in the system.

Much of the information for a diagnostic audit can frequently be obtained directly from plant layout drawings. For smaller facilities, a simple sketch from memory or from a walkthrough might be adequate. Nominal operating information must then be assembled for every energy-consuming component in the system. A number of sources can be utilized for this purpose. Some information can be obtained directly from nameplates on motors, compressors, and blowers. For larger pieces of equipment, manufacturers' operating handbooks are usually available. These handbooks also frequently contain operating curves which show component performance over a range of operation. In preparing a diagnostic audit, it is usually sufficient to select a single operating point which is thought to be typical — say, the efficiency of a motor at 75% load — while for a more detailed analysis, calculations will probably be made at several operating points.

A checklist of energy-consuming areas, such as the one presented in Table 1, may also be helpful in doing a diagnostic audit. This table is not exhaustive, and some additions may be required to adapt it to your situations.

Table 1

Checklist of Energy Consumers.

1. Steam lines; insulation and leaks?
2. Condensate lines: insulation, leaks discharge to drains instead of returning to boiler?
3. Steam traps: leaking or broken?
4. Boiler slowdown: heat recovered or discharged?
5. Boiler feedwater: preheated?
6. Boiler flue gas: excessively high temperature?
7. Electrical equipment: oversized or operating unnecessarily?
8. Lights: overlighted or operating unnecessarily?
9. Air conditioning: oversized or operating unnecessarily?
10. Warehouse temperature and ventilation: unnecessarily high or low?
11. Hot water: unnecessarily high temperature?
12. Compresed air: leaks, unnecessarily high pressure?
13. Boiler maintenance: tubes scaled or sooty?
14. Heated process tanks: open top, insulation?
15. Process furnaces: scheduling, insulation?
16. Process ventilation: run unnecessarily?
17. Waste products: potential use as fuel?
18. Steam pressure: unnecessarily high?
19. Heat treating: unnecessary if new material suitable?
20. Company vehicles: smaller vehicles, carpooling, or computer scheduled routing?
21. Ventilation for space conditioning — proper quantity and hours of use?
22. Space temperatures — exceeding requirements of particular areas or functions?

If engineering data are not immediately at hand, the can usually be obtained from manufacturers' representatives. Manufacturers and utilities representatives can also be of assistance in collecting actual operating data for a

component. For example, electric utility companies usually will, on request, make power factor measurements on major electrical equipment at no charge, and boiler manufacturers may run a flue gas analysis and boiler check for a nominal fee.

In process plants, useful data on flows, temperatures, and pressures may be obtained form process flowsheets. Some care should, however, be exercised in using these figures if the process has been extensively modified since its original design.

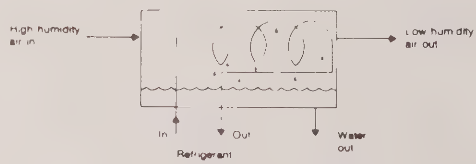
It is helpful to show on the layout drawings technical information on the system operating conditions and other energy-related data, such as insulation thickness on steam pipes. The time spent collecting an organizing basic technical data will pay off in the end. Such information will provide the necessary inputs for a detailed energy analysis of the process and its components, and will make the analysis simpler, faster, and cheaper — whether done by your company personnel or a consultant brought in for this purpose.

If after gathering all the data, you want to take the next step on your own, it would be necessary to begin computing mass and energy balances. Appendix A gives an example showing the specific steps taken in an energy audit. Not all components are as easy to analyze as the example suggests, but using mass and energy balance equations along with available equipment specifications and production data will make possible a reasonable estimate. This estimate could be used to determine whether or not there is a financial incentive to do a more detailed analysis.

On larger, more energy intensive equipment, a more accurate analysis would most probably be justified. In any case, most information collected

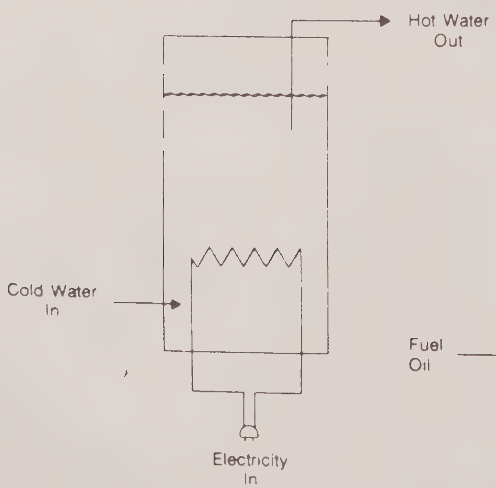
Mass balances

INJECTION MOLDING MACHINE

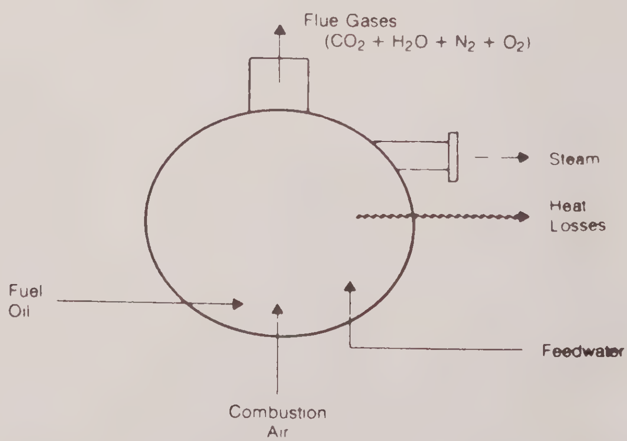


DEHUMIDIFIER

Energy balances



HOT WATER HEATER



BOILER

for a simple analysis would be required in a more sophisticated analysis.

Once you've determined what your chief users of energy are, it is a short step to find ways to reduce consumption in these areas. Potential ideas might include concepts such as revision of processes, use of heat recovery devices, installation of new equipment, and many others. Strictly speaking, current and future costs are not required for an energy audit. Undoubtedly, though, the energy flows identified through this procedure will be translated into dollars and cents to determine whether changes in the system and its operation are justified.

Step 3 — The Periodic Energy Audit.

The diagnostic audit may have suggested that certain key components are especially energy-sensitive, and that it might be well to perform a "periodic" energy audit on a routine basis for these components.

Industrial boilers and process heaters, for example, are frequently the biggest energy consumers within a plant. A diagnostic audit might show that the energy efficiency of the boiler or heater is very sensitive to adjustments in the combustion air intake dampers, and that a periodic check on the status of the combustion air system is needed. The investment of a few hundred dollars in a flue gas analyzer, and a few maintenance man-hours to run a periodic check on the oxygen content in the exhaust gases might easily pay for itself in a month or two through fuel savings in fuel.

A periodic audit procedure can be set up with the assistance of a private technical consultant or a representative of the equipment manufacturer.

Step 4 — The Continuous Energy Audit.

In some instances, particular pieces of equipment may consume enough energy to warrant what might be termed a "continuous" audit. This is done by continuously recording key energy-associated parameters, and frequently computing energy use and efficiency based on these continuous records.

Some examples of a continous audit might include the use of continuous oxygen-measuring instruments in the stack of a refinery process heater, or the continuous record of peak electrical demand in a small manufacturing plant.

Does it pay?

Energy auditing in industrial processes costs time and money. Can you justify the expense? What will be the return on your investment? Of course it is not the audit itself that pays off, but the actions which it suggests. An energy audit can point to those areas having the highest probability of significant savings, and can be used to evaluate the actual savings realized once a modification is made. Let's look at some examples — the company names have been changed, but the figures are real.

Crude Oil, Incorporated, has a 500,000-pound-per-hour boiler for producing process steam. Maintaining dissolved solids at an acceptable level in the feed water requires blow-down at a rate of about 10%. An energy audit on the system showed that about 10 million Btu per hour was being discharged into the waste water pond in the blow-down water. This boiler inefficiency, was costing nearly 14 million Btu per hour in fuel to heat the incoming feed water, or approximately $20 per hour at the contract fuel price. A heat exchanger to transfer heat from the blow-down to the feed costs about $50,000 installed. Payback time: 3½ months!

Parts Manufacturing Company operates two large air compressors for its production facility. The compressors, which are housed in a compressor room, are about 80% efficient, so 20% of the input electric power goes into heating up the air in the room. Room air used to be exhausted to the outside with a ventilating fan. An audit showed that the amount of heat being exhausted was nearly half of that required to heat the company's warehouse space during the winter. A few changes to the ductwork sytem permitted the warehouse return air to be circulated through the compressor room, saving about $1,000 per year in fuel costs.

Words about measurements.

As more detailed accounting procedures are undertaken, it will often be desirable to measure directly certain key quantities, rather than estimating them. Certain measurements can be made using very simple and inexpensive methods; others may require more complicated and costly techniques. Thermometer wells and pressure gauges are relatively simple to install and are quite inexpensive. Measurement of fluid flow is somewhat more difficult. However, if the

measurement is to be made only occasionally (for a periodic energy audit, for example), certain "quick and dirty" methods may be used.

The rate of steam consumption in a steam-jacketed cooker, for example, can be determined by draining the condensate into a bucket and weighing the bucket after a measured period of time. If the condensate is above atmospheric pressure, care must be taken to avoid flashing the liquid to steam, both for safety reasons and for accuracy in the flow measurement. One means of overcoming this problem is to start with the container partially filled with cold water, then drain the condensate through a submerged tube. Any steam resulting from the drop in pressure will be condensed by the cold liquid, and the change in the weight of the container can be determined after the measured time span.

Another technique suggested by one clever plant engineer includes measuring flow rates from compressed air lines. By simply discharging the line into a large plastic garbage bag, the quantity of "air" is measured.

In both of these examples, it is assumed that the conditions are such that opening the flow to the atmosphere will not significantly alter the conditions which existed when the system was closed. In all measurements, care must be taken to ensure that the quantity being measured is not altered by the measurement process itself. For example, a piece of insulation should not be removed in order to measure the pipe wall temperature. The heat leak thus introduced would lower the temperatures such that an inaccurate indication of the conditions existing under the insulation would be obtained. Similarly, thermowells installed in pipes may present a new heat leak path. Thus, care must be taken to properly insulate all installations to assure preservation of the undisturbed conditions.

Other measurements, such as flue gas composition in a boiler or process heater, may be made periodically using portable instrumentation obtainable for a few hundred dollars. Many small companies are investing in pistol-type non-contact thermometers which measure approximate temperatures of surfaces from their infrared emissions. These devices are reasonably reliable and can be used by untrained maintenance personnel for periodic checks.

Measurements for continuous energy monitoring are generally more complex, since they usually involve electrical sensors and electronic recording devices. Advice regarding the pros and cons of various systems can be obtained from equipment manufacturers or instrumentation consultants.

Instrumentation is one of the fastest growing and most competitive areas of modern technology. Since energy auditing involves information, and information means measurement, the development of an up-to-date file of current instrumentation literature pertinent to the company's processes is an important element of the energy management program.

Summary:

The four levels of energy audit form a natural step-by-step progression. At all levels, the object is to produce information which can be used in the energy management feedback loop. Management means control, and adequate control cannot be accomplished without a knowledge of the system being controlled.

At the lower levels of energy accounting, the "control system" might be the plant manager himself, and his "control signal" might be a change in operating procedures or the replacement of a piece of hardware. At the higher levels, control might literally be exercised through the use of an electronic device which actually exerts a continuous influence on plant operations to minimize energy costs. In any case, a clear picture of the plant's energy utilization, obtained through an energy audit, will invariably result in more efficient operation.

APPENDIX A

Exchange of Energy Audit

Alberta Feed Products Company is a rendering plant which dehydrates the by-products of slaughtering operations into solids and fats. The solids are used as high protein additives in animal feed, and the fats for tallow in soap products.

Rendering is an energy intensive process, thus the economics of the business depend strongly on the fuel price and rate of consumption. AFPC's profits, like those of many other industries, have been affected by escalating energy costs. In early 1975 the company instituted an energy management program. As a first step, a historical energy audit was done by the bookkeeper.

ALBERTA FEED PRODUCTS COMPANY
PLANT ENERGY USE DATA FOR 1975

Month	No. of Units Produced (10^6 Pounds)	Electricity (Kw-Hr.)	Natural Gas MCF	Natural Gas BTU/MCF	Natural Gas Total (10^9 BTU)	BTU/Lbs. Produced (10^3)	KWH/Lbs. Produced (10^5)
Jan.	7.90	316,667	12,852	970,000	12.46	1.577	4008
Feb.	6.95	279,781	11,257	970,000	10.92	1.571	4025
Mar.	8.10	324,581	12,910	970,000	12.52	1.545	4007
April	7.05	282,895	11,190	970,000	10.85	1.539	4012
May	7.65	306,685	12,107	970,000	11.74	1.535	4009
June	8.00	320,675	12,621	970,000	12.24	1.530	4008
July	8.20	328,590	12,931	970,000	12.54	1.529	4007
Aug.	7.65	306,445	12,113	970,000	11.75	1.536	4005
Sept.	7.45	298,619	11,779	970,000	11.43	1.534	4008
Oct.	7.73	309,852	12,341	970,000	11.97	1.548	4008
Nov.	7.50	300,932	12,384	970,000	12.01	1.601	4012
Dec.	7.80	312,857	12,804	970,000	12.42	1.592	4011

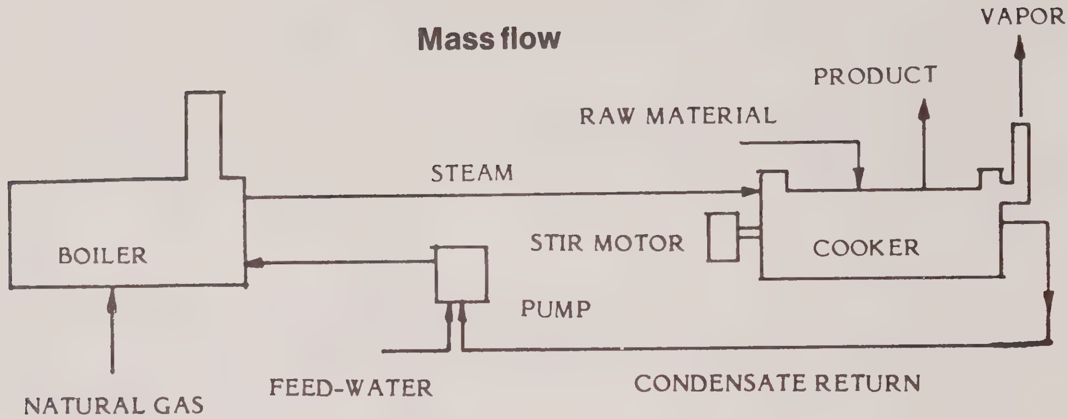
A major finding of the historical audit was that natural gas consumption per unit output in colder months was higher than average and usually a little higher in low volume months.

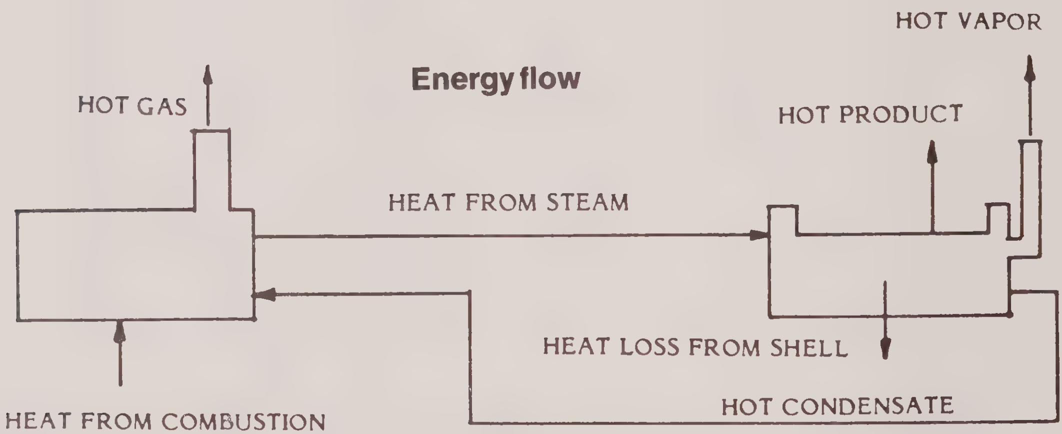
Obviously a diagnostic audit of major plant components was in order. A quick survey of the facility showed the following major pieces of equipment using purchased energy.

Boilers	Electric Motors
2-600 horsepower	6-60 horsepower
1-300 horsepower	2-50 horsepower
	3-30 horsepower
	1-150 horsepower chopper
	1-100 horsepower hammer mill
	1-200 horsepower screw press

The rendering process is done in a batch mode. About 5000 pounds at a time are loaded into large steam jacket cookers. As the batch is heated it is continuously stirred by a large electric motor. Since natural gas is the major utility cost and represents the single largest cost of operation, the manager decided that a diagnostic audit of the boilers and cookers seemed the most profitable first step.

The first step in a diagnostic audit is to diagram the mass and energy flows.





After completing the diagrams, the manager could easily see where energy inputs were required and where energy losses were occurring. The next task was to quantify both the amounts of energy used in the process and the associated losses. Compared to the boilers, the cookers are relatively easy to analyze, therefore, the manager chose to analyze the cookers first.

Since a known amount of raw material is supplied in each cooking cycle and a known amount of product is produced, the difference between what was entered and what remains is the evaporated water. The manager knew from experience that about 55% of the weight of the raw material remained after processing, and that the remaining material is about 50% fats and solids, and about 5% moisture content remains in the product.

Using formulas from Table 2 the manager could calculate the amount of energy required to heat the material (solids and water) to boiling, as well as the energy required to boil off the moisture.

Table 2

Formulas for Estimating Energy Content of Plant Utilities

Energy in hot water

$$\text{Energy}_{HW} \text{ (in BTU's)} = W\,(T_{Hot} - T_{Cold})$$

Where: W is the weight of water in pounds (or flow rate in lbs/hr)

T_{Hot} = the hot water temperature in degrees F

T_{Cold} = cold water temperature in degrees F

Energy is saturated steam

$$\text{Energy}_{St} \text{ (in BTU's)} = \text{Energy}_{HW} + (Hv \times W)$$

Where: Energy_{HW} is the energy content of boiler water (use formula 1 and take T_{Hot} as the boiling point (see table below) and take T_{Cold} as the condensate return or feedwater temperature.)

Hv is the heat of vaporization (see table below):

Steam Pressure	Boiling Point	Hv
14.7	212	970
50 psig	298 degrees F	911 BTU/lb.
100	338	880
150	365	857
200	388	837
250	406	820
300	422	799
500	470	751

Energy to produce compressed air

$$\text{Energy}_{CA} \text{ (in kilowatts)} = \frac{\text{Brake HP}}{\text{CFM}} = (\text{CFM}) = (.75)$$

Where: $\frac{\text{Brake HP}}{\text{CFM}}$ is obtained from the table below and CFM is the number of cubic feet per minute of air produced.

Air Pressure (psig)	Single Stage Comp.	2-Stage Comp.
50	.15	.15
75	.19	.17
100	.22	.19
125	.25	.21

If you assume that each 5000 pound batch is 50% water and that the average ambient temperature is 70 degrees F, then you may estimate the energy requirement to heat the water content of the material to the boiling point. (The energy required to heat the solids and the losses from the cooker shell are negligible.)

Energy to heat water = pounds $(T_{Hot} - T_{Cold})$

Energy to heat water = (5000 x .5) (212 − 70)

Energy to heat water = 2500 (142)

Energy to heat water = 355,000 BTU/batch

If you further assume that 45% of the total weight is boiled away and you know that it takes 970 BTU/lb. to change 212 degrees F to 212 degrees F steam, (From Table 2), you can calculate the energy required to dehydrate a 5000-pound batch.

Energy for phase change = pounds x Hv

Energy for phase change = (5000 pounds x 45%) x 970 BTU/lb.

Energy for phase change = 2,182,500 BTU/Batch

It is obvious that the energy required to evaporate the water is much greater that the energy to heat the product to 212 degrees. All of the 2,182,500 BTU's used to evaporate the water are going into the atmosphere. Recovery of this energy represents a significant opportunity for savings.

One possibility is to use the waste heat to preheat the next batch of product. This would save not only energy and dollars but would speed up the batch process and allow more production per cooker each day.

The manager contacted a rendering equipment manufacturer to discuss the design and cost of equipment to recover the energy in the waste steam.

The manager continued his conservation efforts by examining the boilers and electrical equipment. Here too, he found that technically feasible modifications could save energy. Like the possible modifications on the cookers, these too were evaluated for financial soundness. Those found to be both technically and financially feasible were implemented. The manager also decided to form a company energy conservation task force with various members responsible for keeping records and checking the efficiency of equipment on a regular cycle. In this way the manager hoped to develop a periodic audit procedure to keep the company profitable and take advantage of cost effective energy conservation opportunities.

APPENDIX B

Example of an Energy Budget — Theoretical Calculation

For the purpose of this example it is assumed you are endeavouring to ascertain the energy consumed by a water wash tank in the plating room.

The tank is filled and heated every Monday morning in 1 hr. starting at 7 a.m. and maintained at 150° F. until it is drained on Friday afternoon at 5 p.m. (a total of 106 hours). This happens 50 times a year.

The work load of the tank (i.e. parts washed) amounts to 100 pounds of steel per hour. The parts are immersed in the water for 1 hour, entering at 70° F., 8 hrs./day.

The tank is 2 feet wide, 3 feet long and 2 feet deep.

The water depth is 1 ½ feet and is maintained at this depth by adding make-up water at the rate of 1 gallon per hour. Fresh water temperature is 50° F. The ambient temperature is 70° F.

The total theoretical energy input to the dipping tank is calculated for two conditions.

1. tank walls uninsulated and no cover on top.
2. tank walls insulated with 1" of foamed polystyrene and top covered with plastic spheres.

PHYSICAL CONSTANTS

Water:	sp. ht.	— 1.0 btu/lb/°F.
	heat of fusion	— 140 btu/lb.
	heat of vaporization	— 960 btu/lb.
	density	— 62.4 lbs/cu. ft.
Steel Tank:	sp. ht.	— .12 btu/lb/°F.
	density	— 492 lbs/cu. ft.
	thickness	— 1/8 inch

WEIGHTS & AREAS

Volume	= 2′ x 3′ x 1 ½′	= 9 cu. ft.
Wt. of water	= 9 x 62.4	= 561.6 lbs.
Area	= 3(2 x 3) + 2(2 x 2)	= 26 sq. ft.
Wt. of tank steel	= $\frac{26 \times .125 \times 492}{12}$	= 133.3 lbs.
Top area	= 2′ x 3′	= 6 sq. ft.

A. HEAT-UP REQUIREMENTS

Fundamental formula:

Weight (lbs) x sp.ht. (btu/lb/°F.) x temp. rise (°F.) plus
Weight (bls) x Heat of Fusion/Vaporization (btu/lb.)

Start-up heat absorbed by:		Tank:		Uninsulated btu	Insulated btu
Water	= 561.6 x 1.0 x (150° — 50°) + 0			56,160	56,160
Tank Steel	= 133.3 x .12 x (150° — 50°) + 0			1,600	1,600
	Total absorbed			57,760	57,760
Losses* from:		Uninsulated	Insulated		
Tank sides	26 sq. ft. (a)	188 btu/sq. ft.	28 btu/sq. ft.	4,900	730
Water surface	6 sq. ft. (a)	917 btu/sq. ft.	228 btu/sq. ft.	5,500	1,370
	Total losses per hour			10,400	2,100
Working heat absorbed by:					
Steel parts	= 100 lbs. x .12 x (150° — 70°) + 0			960	960
Make-up water	= 10 lbs. x 1.0 x (150° — 50°) + 0			1,000	
Make-up water	= 2.5 lbs. + x 1.0 x (150 — 50) + 0				250
	Total input per hour			1,960	1,210
OPERATION					
Heat up	— absorbed in first hour			57,760	57,760
	— average loss in first hour	$\frac{\text{total losses}}{2}$		5,200	1,050
Working	— input per hour x 8 hr x 5 days per week			78,400	48,400
	— losses per hour x 106 hours per week			1,102,400	222,600
Total energy input per week				1,243,760	329,810
Potential Weekly Saving		(73.5%)			913,950

**available from published curves*
+ evaporation reduced by covering

APPENDIX C

Charts for use in an Energy Conservation Program

Chart 1

Industry: An Energy Budget

Energy use by consumption area and process steps	Actual Energy Used	Theoretical Energy Requirement	Variance between theory & practice	Goal	Change from Previous Month
Examples					
Buildings & Grounds					
Heating					
Shipping					
Lighting					
Machinery					
Receiving					
Laboratory					
Shop					
Assembly					
Combustion					
Waste Disposal					
Cooling					

Chart 2

DEPT. __________

Energy Conservation Survey (Sample sheet)

DATE __________

LOCATION	FUEL GAS or OIL LEAKS	STEAM LEAKS	COMPRESSED AIR LEAKS	CONDENSATE LEAKS	WATER LEAKS	INADEQUATE INSULATION	EXCESS LIGHTING	EQUIPMENT OPERATING UNNECESSARILY	BURNERS OUT OF ADJUSTMENT	UNNEEDED HEATING OR AIR COND	PHOTOCOPY MACHINE			DATE CORRECTED
SHIPPING														
RECEIVING														
LABORATORY														
SHOP														
ASSEMBLY														
CHEMICAL STORAGE														
COMBUSTION														
FURNACE ROOM														
UTILITIES														
ADMIN· OFFICES														

Chart 3A

DEPT. ________ Monthly Energy Use by Department **DATE** ________

1976	ELECTRIC POWER			NATURAL GAS			FUEL OIL			COAL			COMPRESSED AIR			
	MWh	BTU/MWh	BTU	Mcu ft	BTU/Mcu. ft.	BTU	Gal	BTU/Gal	BTU	TONS	BTU/lb	BTU	Mcu ft	BTU/Mcu. ft.	BTU	
Jan.																
Feb.																
Mar.																
April																
May																
June																
July																
Aug.																
Sept.																
Oct.																
Nov.																
Dec.																
Total																

Char 3B

DEPT. ________ **Monthly Energy Use by Department** DATE ________

1976	psig STEAM			Condensate Used or Lost			WATER			TOTAL CONVERSION BTU	No. of Units Produced	Conversion BTU Per Unit of Production	
	M lb.	BTU M lb.	BTU	M lb.	BTU/M lb	BTU	M lb.	BTU/M lb	BTU				
Jan.													
Feb.													
Mar.													
April													
May													
June													
July													
Aug.													
Sept.													
Oct.													
Nov.													
Dec.													
Total													

Sample of an Energy Conservation Check List

Department ______________________________ Date ____________

STEAM SYSTEMS:

Steam at ______ psi, ______ pph winter peak, ______ pph summer demand.

1. Is steam being used at proper pressure for the application? ________
2. Is piping insulation adequate? ________
3. Are all steam traps operating properly? ________
4. Are additional steam traps needed? ________
5. Is all condensate returned to the boiler? ________
6. Can thermal fluids be used for more efficient heating? ________

Comments ______________________________

____

AIR MANAGEMENT SYSTEMS

1. Are proper temperatures maintained both summer and winter? ________
2. Is humidity control adequate for the operation? ________
3. Is the area properly insulated to minimize heat loss? ________
4. Are exhaust ducts located close to source of fumes? ________
5. Is provision for makeup air adequate? ________
6. Is exhaust from processes such as spray booths automatically controlled? ________
7. Can amount of exhaust air be reduced? ________
8. Is heat recovered from exhaust air? ________
9. Can heat loss be reduced from doors, windows? ________
10. Can timers control heaters, fans, chillers more efficiently? ________

Comments ______________________________

____

COMPRESSED AIR: Consumption _____ cfm at _____ psi.

1. Are there any leaks in compressed air piping? _____
2. Can small compressors handle after-hours loads? _____
3. Is compressed air properly dried at the compressor? _____
4. Is compressed air properly lubicated where needed? _____
5. Is oil-free air supplied where necessary? _____
6. Are compressed air pressures properly matched to the application? _____
7. Can lower pressure air be substituted for high pressure air? _____

Comments ____

____

ELECTRICITY

Voltages available __________ , peak electrical demand __________

Total hp induction motors __________ , power factor __________

1. Can peak demand be reduced by cycling non-critical loads? _____
2. Is power factor correction adequate? _____
3. Should synchronous motors be used on larger loads? _____
4. Is voltage adequate on all circuits? _____

Comments ____

____

LIGHTING: Lighting supplied by (no.) __________ (type) __________ fixtures rated at __________ watts.

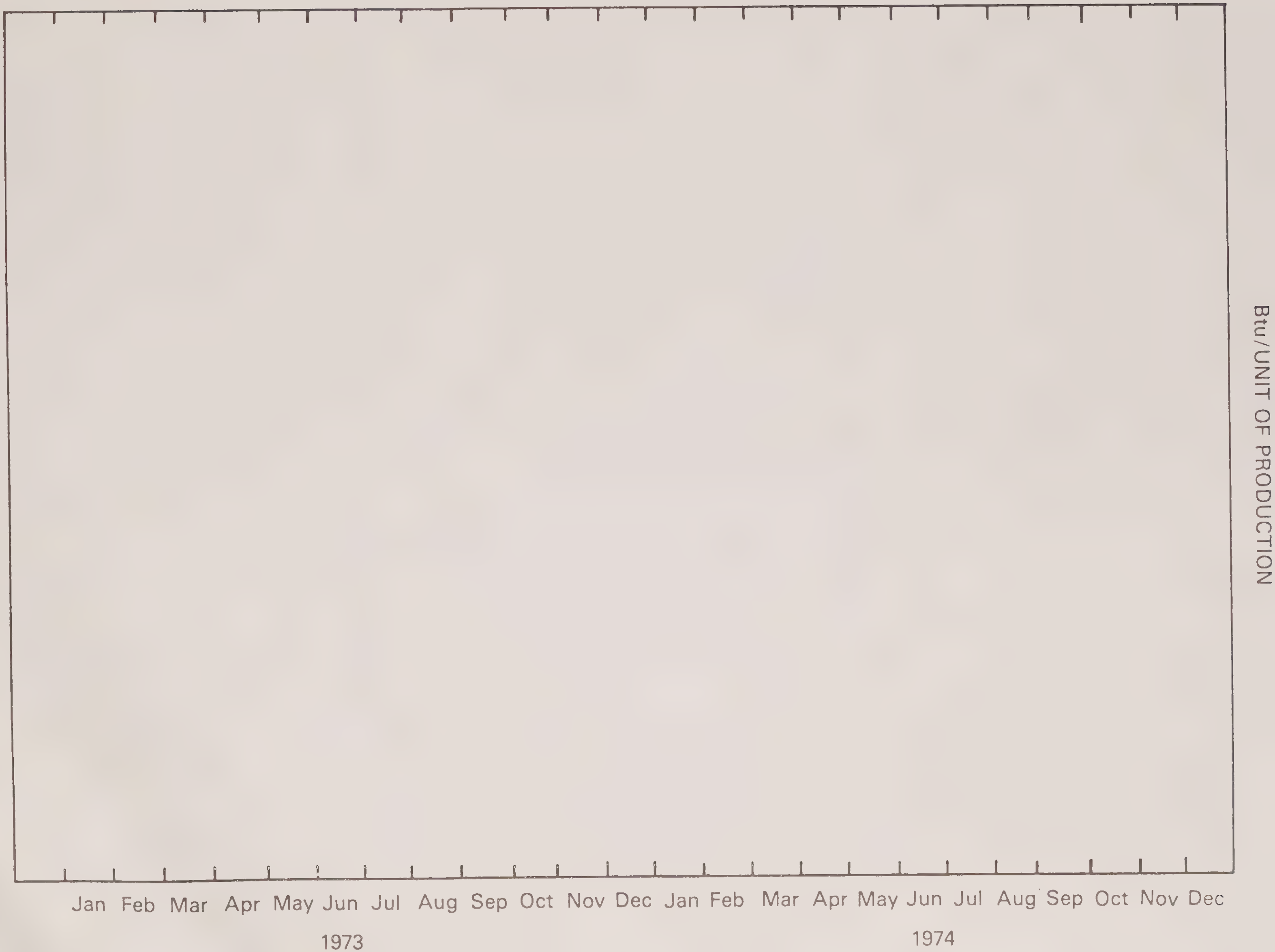
1. Is lighting level suitable for type of activity in the area? _____
2. Who is responsible for turning lights off when not needed? _____
3. Are lighting circuits designed to allow minimal safety lighting? _____
4. Can timers, photoswitches, control exterior lighting? _____
5. Can incandescent lights be replaced with more efficient types? _____

Comments ____

____

Chart 6 Tracking Chart

Energy Use Per Unit of Production



APPENDIX D

Ontario Ministry of Industry and Tourism Energy Audit

Ontario

Ministry of Industry and Tourism

ENERGY AUDIT

(Confidential)

The purpose of this audit is to:

1. Permit an "on the spot" computer analysis of your energy use and estimate of possible savings.
2. Assist you to develop and implement an energy program to realize these savings.

The form is in two parts. The first is general information about your plant. The second is electrical consumption which can be obtained from your files or directly from your hydro utility if more convenient. Both parts are necessary for the audit.

Company Name		
Address		
Energy Contact	Tel. No.	Date

PART I
CURRENT ENERGY COSTS AND RATIOS

	Units	Cost per Unit	Cost per Year
Electricity	KwH	$.	$
Fuel Oil	Gallons	.	
Natural Gas	M.C.F.	.	
Coal	Tons	.	
Propane	Lbs.	.	
Water	1000 Gals.	.	
		Total	

Annual Sales	$	
Energy as % of Sales		
*Production Units		*Select production units such as pounds, tons, cases suitable for your plant. Use to establish year to year trends.
Energy as dollars/Production Unit		

INSULATION ANALYSIS

	Length	Width	Height	Floor Area	Perimeter
Building	Ft.	Ft.	Ft.	Sq.Ft.	Ft.

Construction	Material	Thickness	Insulation Type	"R" Factor (If known)
Wall				
Roof				

Window Area	% of Wall	☐ single pane ☐ double pane	Skylight Area	% of Roof	☐ single pane ☐ double pane

Comments:

IT 1533A (8/76)

HEATING AND AIR-CONDITIONING

	Type	No.	Size	Fuel	Total BTUs/Hr
Boilers					
Unit Heaters					
Furnace					
Electrical					
Air Conditioners					
Other					

Air Recirculated	☐ Yes	☐ No

Comments:

EXHAUST HEAT ANALYSIS

Exhaust Air

	Blower/Fan Function	Rated C.F.M.	Actual C.F.M.	Exit Air Temperature
1				
2				
3				
4				

Air Make-Up

	BTU Per Hour Input	Rated C.F.M.	Actual C.F.M.	Air Temperature
1				
2				
3				
4				

Comments:

LIGHTING ANALYSIS

Location	Description of Lighting System	Foot Candles at Working Level

WATER ANALYSIS

Gallons Used Per Year	Cost Per Year	Sewer Surcharge Per Year	
Input Temperature	Discharge Temperature	Hours Discharged Per Day	Days Discharged Per Year
Water Used For 1.	2.	3.	

Compressed Air Analysis

No. of Compressors	Hours of Operation	Rated H.P.

Process Heat Analysis

Source of Heat	Inlet Temp. °F	Outlet Temp. °F	Consumption Per Hour	Outflow Per Hour
*Air			cu. ft.	cu. ft. *
Steam			Lbs.	Lbs.
Hot Water			Gals.	Gals.
Cooling Water			Gals.	Gals.

*In ovens, furnaces, unit heaters where gas or oil is burned, use the total of fuel and combustion air plus any excess air if present in the outflow.

Comments:

IT 1533B (8/76)

PART 2 – ELECTRICAL POWER ANALYSIS

Please tabulate the last twelve monthly electrical meter readings. Required are:

Demand Kilovolts – Amps. – KVA. Demand Kilowatts – KW. Consumption in Kilowatt Hours –KWH

NOTE: The BILLED DEMAND KW and the METERED KW may be different. If your billing does not indicate BOTH, it will be necessary to obtain this information from your local hydro.

MONTH	KVA	KW	KWH
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

DEMAND CHARGE

First	KW @ No Charge	
Next	KW @	$ /KW
Remaining	KW @	$ /KW
Voltage Transformation Discount (if you own transformer)	@	cents /KW
If own transformer, do you pay 1.5% Metering Penalty?	☐ Yes	☐ No

ENERGY CHARGE

First	KWH @	¢/KWH
Next	KWH @	¢/KWH
Next	KWH @	¢/KWH
Next	KWH @	¢/KWH
Remaining	KWH @	¢/KWH

Comments:

Approval For P.U.C. to Release Information

Name	Title	Signature

IT 1533C (8/76)

Assistance for ...ervation — The ...evelopment Program

To suppo... ...rgy conservation measures in industry, including waste heat recovery, the Department of Industry, Trade and Commerce is administering its Enterprise Development Program (EDP) to ensure that it supports energy efficiency and if it meets the other criteria of the set out here. If a project can demonstrate the possibility of significantly improving energy efficiency and if it meets the other criteria of the programs, assistance may be granted.

Effective April 12, 1977 the Enterprise Development Program (EDP) replaced the following Industry, Trade and Commerce innovative and adjustment assistance programs:

- **PAIT** — Program for Advancement of Industrial Technology
- **IDAP** — Industrial Design Assistance Program
- **PEP** — Program to Enhance Productivity
- **GAAP** — General Adjustment Assistance Program
- **AAA** — Automotive Adjustment Assistance Program
- **FTIAP** — Footwear and Tanning Industry Adjustment Program
- **PIDA** — Pharmaceutical Industry Development Assistance Program

EDP combines the basic features of these programs and is designed to facilitate co-ordination amongst various forms of assistance making Industry, Trade and Commerce programs more accessible to Canadian industry, particularly smaller and medium-sized businesses.

The EDP Program is administered by the Enterprise Development Board and the regional Enterprise Development Boards all of which report to Cabinet through the Minister of Industry, Trade and Commerce.

EDP objectives

The overall objective of the EDP Program is to enhance the growth in the manufacturing and processing sectors of the Canadian economy by providing assistance to selected firms to make them more viable and internationally competitive.

The thrust of the EDP Program is to increase the effectiveness of the Department's industrial support programs to foster innovation and adjustment. The focus for assistance is on promising smaller and medium-sized firms prepared to undertake relatively high risk projects in relation to their resources which are viable and promise attractive rates of return on the total investment.

How EDP works

There is a typical product life cycle through which all products pass. Generally, this cycle entails the following distinct phases:

a) concept; b) development; c) pre-production; d) production; e) marketing.

Previously, incentive and development programs have been oriented to certain phases of the product life cycle. For example, PAIT was oriented to the concept, development and pre-production phases, while GAAP was oriented to the pre-production, production and marketing phases.

But there are differing problems and risks facing a firm at all phases of the product life cycle. The corporate approach endeavours to examine all of the problems and risks facing a firm at each of the distinct phases of a product life cycle.

Standard operating policy for the EDP Program is to adopt the corporate approach to analysis, that is, to undertake a rigorous analysis of applicant firms and their proposed projects to identify viable businesses with attractive future prospects. The orientation is towards the business plan of the firm to identify present and future requirements for assistance and to tailor one or more forms of assistance under the program together with other government assistance and private sector financing into a "do-able" financing package to suit the applicant company.

This flexible approach is described as "merchant banking" flexibility. A merchant bank

is defined as a financial institution which endeavours to serve its clients by identifying, structuring and providing (or arranging for) all of the types of financing, and financial and management services which are required by a firm to realize its full potential.

This approach may be described as investing in firms, not just supporting projects.

The corporate/merchant banking approach is similar to that of an investor. That is, the approach is to examine the resources of the firm (human, financial, physical and technological); to examine the market opportunities and constraints; and to examine the plans of the firm to marshall its present and attainable resources to exploit its present and future market opportunities.

The decision-making structure

The decision-making structure for the program is addressed in two ways:

a) The decision-making structure for the program is mixed private sector/public sector boards. This is designed to provide pragmatic, market-oriented decisions by using the experience of prominent businessmen in the decision-making process. Further, this provides the responsible officer with guidance and advice in the analysis of firms, and in structuring "do-able" packages of assistance.

Strict confidentiality and conflict of interest guidelines protect the competitive interests of applicant firms.

b) Secondly, the decision making is decentralized to a greater extent with the creation of regional boards with delegated approval limits. This is designed to provide faster decision-making and an awareness of regional business conditions in the decision-making process.

Forms of assistance

The following components of the EDP Program indicate the various forms of assistance available:

a) grants to develop proposals for projects eligible for assistance

b) grants to study market feasibility

c) grants to study productivity improvement projects

d) grants for industrial design projects

e) grants for innovation projects

f) loans and loan insurance for restructuring (plant expansion, equipment modernization, working capital, etc.)

g) special purpose forms of assistance-surety bond guarantees, footwear or tanning industries assistance, DHC-7 sales financing assistance.

Within the context of the overall objective of the EDP Program, each of the various forms of assistance has sub-objectives as described below:

a) **Grants to develop proposals for projects eligible for assistance**

In order to ensure that the more complex proposals for innovation and adjustment assistance are developed on a viable, adequately researched and workable basis, grants to partially offset the cost of qualified consultants can be provided to this end.

b) **Grants to study market feasibility**

Projects for innovation and restructuring often falter or fail due to problems related to markets and marketing. To reduce the risk of projects in this regard, grants to partially offset the cost of the services of expert consultants in this field can be provided before innovation or adjustment assistance is considered.

c) **Grants to study productivity improvement projects**

To encourage feasibility studies of productivity improvement measures which do not require technology which is new to the firm but do involve some risk, grants to partially offset the cost of consultants qualified to conduct such feasibility studies can be provided.

d) **Grants for industrial design**

The objective of grants for industrial design is to assist and to generally promote greater use of qualified industrial design services for products to be mass produced.

e) **Grants for innovation projects**

The purpose of innovation assistance is to increase technological innovation in Canada

where it will lead to industrial growth and economic benefit to both the firm and to the Canadian economy. Grants can be provided to selected projects concerned with the development of new or improved products and processes or service capability incorporating an advance in technology and offering good prospects for profitable commercial exploitation.

Due to the risk and uncertainty which accompany innovation projects, this type of assistance should frequently be provided in conjunction with other forms of assistance, for example, grants to study market feasibility.

f) **Loans or loan insurance for adjustment projects**

The basic purpose of the adjustment assistance aspects of the EDP Program is to facilitate restructuring or rationalization of manufacturing and processing firms in Canada by providing last resort financial assistance. Canada's secondary manufacturing industries frequently have considerable difficulty in meeting international competition both at home and in export markets. While the problems are numerous and complex, one frequent problem is that Canadian manufacturers have in many cases been geared to serve domestic markets under protective tariffs. In order to enhance the viability of secondary manufacturing and processing and to permit Canadian firms to become more internationally competitive, massive private investment in restructuring operations and modernizing equipment and facilities is required. In some cases, usual sources of financing for this purpose are inadequate for some smaller and medium-sized firms and in these cases, loan insurance (guarantees) can be provided through the adjustment assistance components of the Enterprise Development Program.

Direct loans can also be provided to viable Canadian firms engaged in manufacturing or processing but this assistance is restricted to cases where firms have been injured by import competition.

Due to the risks frequently associated with last resort financial assistance, this type of assistance may frequently be provided in conjunciton with other forms of assistance, for example, grants to develop restructuring proposals or grants to study productivity improvement projects.

g) **Special purpose forms of assistance**

The adjustment assistance aspects of the Program are occasionally utilized to structure special purpose forms of assistance to meet more specific objectives.

Three forms of special purpose assistance which are in place are:

i) loans and grants to encourage restructuring of firms engaged in footwear or tanning industries;

ii) insurance on surety bonds for off-shore turnkey projects; and

iii) insurance on loans, leases and conditional sales agreements to air carriers in Canada and the United States to acquire de Havilland DHC-7 aircraft.

These three special purpose forms of assistance are administered by the Central Board and are not included in the delegated approval authority of the regional boards.

Who is generally eligible for assistance?

As a general statement, the orientation of the Enterprise Development Program is to provide assistance to smaller and medium-sized firms engaged in manufacturing or processing activities. Firms in the service sector are, under limited circumstances, also eligible provided the provision of services provides direct, tangible and significant benefit to firms engaged in manufacturing or processing, or the project (such as an innovation project) is to be exploited by a firm engaged in manufacturing or processing activities.

As a matter of policy, the Board will restrict the availability of such assistance to cases where the benefitting manufacturing firm is eligible for assistance.

Applicants for innovation and industrial design assistance must be incorporated. Firms applying for adjustment assistance need not be incorporated to be eligible. However, it is highly desirable that all firms are incorporated before receiving assistance, not only for the Crown's benefit but also for their own benefit. The Crown prefers to deal with limited companies as non-personal legal entities. From the firm's point

of view, incorporation provides protection to its principles by limiting their liability under business obligations.

Each of the various forms of assistance has certain criteria, but generally, the eligibility criteria are as follows:

a) the firm and the project must be viable;

b) for loans and loan insurance, the firm must be unable to obtain financing on reasonable terms; and

c) for grants, the project must represent a significant burden to the firm in respect of its resources.

For more information on the Enterprise Development Program please contact The Program Office, IT&C Ottawa or your nearest Industry, Trade and Commerce Regional Office.

Degree days

In determining — and improving — the efficiency of heating equipment, the concept of "degree days" represents a convenient means of factoring climatic conditions into calculations.

Essentially, degree days provide a 'climatic correction' for efficiency measurement and enable an allowance for weather variations to be made when comparing the efficiency of heating plants for one heating season with the efficiency of equipment during a previous season.

Degree days are also sometimes used as a factor in predicting future heating fuel consumption. However, care must be taken here.

What is a degree day?

The generally accepted definition of a degree day is the daily difference between a base temperature of 18°C and the 24-hour mean outside temperature (when it falls below the base temperature).

It goes without saying that more heat and therefore more fuel is required to maintain an office or factory at a comfortable temperature in cold weather than is required in warm weather. Equally obviously, a heating installation should maintain comfort in inhabited buildings, despite climatic changes in the outside temperature, by keeping to a set room temperature.

Experience and tests based on careful observation have indicated that heat requirements (i.e. fuel consumption) of buildings which maintain an inside temperature of 21°C are closely related to the amount by which the outside temperature falls below 18°C. The explanation of this difference lies in the fact that not all the heat requirements of a building are supplied from its heating plant. Other sources of heat such as people, lift-motors, processes, lights, etc., supply sufficient heat to raise the internal temperature on average by some 3°C. This figure may vary with occupancy and standards of thermal insulation, but for normal use a difference of 3°C is acceptable.

Heat consumption in any given period depends upon temperature and time. Assuming that an outside temperature of 17°C prevails for one day, heating requirements are proportional to (18-17)°C, i.e. 1°C for that day. This one degree difference between outside temperature and 18°C maintained for one day of 24 hours is called

Relationship of degree days to energy consumption

Period	*Degree days (°C)*		*Fuel Consumption (Gallons)*		*Gallons/Degree day*	
	1973/4	1974/5	1973/4	1974/5	1973/74	1974/5
October	172	237	2,842	2,049	16.5	8.6
November	286	237	4,686	2,087	16.4	8.8
December	319	218	5,318	1,886	16.7	8.7
January	280	254	4,586	2,152	16.4	8.5
February	274	291	4,544	2,510	16.6	8.6
March	296	313	4,904	2,763	16.6	8.8
April	207	212	3,469	1,910	16.8	9.0
Total October/April	1,834	1,762	30,349	15,357	16.6	8.7

'one degree day'.

If outside temperatures remained at 17°C for each day of a week, a total of seven degree days would be accumulated. In the same way an outside temperature of 16°C for one week would accumulate two degree days each day, making 14 degree days for the week. It can then be inferred that fuel consumption for the second week would roughly be twice the fuel consumption for the first week.

Unfortunately, temperature does not remain constant during the day so that it is necessary to calculate degree days from temperature readings in a less straightforward manner, which is explained later in this section.

How do degree days relate to fuel used?

Degree day data may be used to establish whether fuel used for heating buildings is being consumed efficiently. In the first instance, a direct comparison may be made between fuel used over a period with the number of degree days in the same period. Month-to-month variations in fuels used can be explained by proportional changes in degree days or, more effectively, the factor of 'fuel used per degree day' can be derived. This is illustrated by the chart on page 33.

This application of degree days may be of particular interest to supervising engineers who control the heating of a number of buildings of the same type and construction, or because the factor 'fuel used per degree day' can give a useful guide to the likely consumption of fuel in buildings of similar character and size. Even if these buildings are located in different parts of the country the method is still applicable, because up-to-date degree day figures for appropriate areas are available from Fisheries and Environment Canada.

How degree days should not be used.

- If degree day figures are used for short period tests, consistent results cannot be expected.
- Daily or weekly degree days are unlikely to be satisfactory and can give misleading results; it is recommended that monthly figures be used.
- For some industrial and other uses, inside temperatures may have to be maintained at temperatures higher than 21°C. For example, operating theatres in hospitals need an inside temperature of 27°C. For protection against frost some rooms may need to be kept about 8°C. Degree days based on inside heating to 21°C are not valid in such special applications.
- It should be noted that in those buildings where the internal heat output fluctuates significantly (e.g. intermittent use of heat producing machinery), degree days may not give a reliable indication of fuel usage. For buildings where the internal temperature rise is consistent, even if it falls short of, or exceeds, 3°C, relative comparisons based on degree days are valid.

Divergence of warmest and coldest months from 19-year average (1957/8-1975/6).

How accurate are fuel calculations based on degree days?

When related to fuel consumption, degree days assume 'continuous' heating even though buildings may be unoccupied at night and during the weekends. One way to overcome this is to calculate 'intermittent' degree days which would be directly related to the occupied hours of buildings. In order to do this special temperature readings applying to the periods of occupancy have to be obtained. However, buildings with a high thermal capacity take a long time to cool down (or warm up) and for them breaks of less than a day may not be significant.

Fuel consumption is not solely related to temperature. There are other meteorological influences such as wind strength, humidity, solar radiation and cloud, physical characteristics of the building, and the manner in which it is used which also have a significant effect. In addition, for short periods, heat requirements may not be typical of the whole heating season. This makes comparison of fuel consumption with degree days for short terms invalid.

With self-contained heating installations, heating plant efficiency alters in accordance with the demands put upon the system as a whole. Efficiency will probably be lower early and late in the heating season when the load is lighter but will improve as load increases during colder weather.

These factors must be taken into account when considering fuel consumption — and the results obtained seen in this light.

The care necessary in using degree days to predict fuel consumption is illustrated in the chart at left. It shows the variation in monthly degree days between the warmest and coldest month during a 19-year period (for which the data is available). In estimating fuel requirements for, say, December using the calculated figure based on average degree days for December, it is possible that in an individual month between 30 percent less and 20 percent more may be required.

The degree days concept obviously has its limitations. But if used intelligently, it can be an extremely useful tool. (See pages 36 and 37.)

Conversion of monthly heating degree-days from Fahrenheit to Celsius

D. W. Boyd of the Atmospheric Environment Service, who is attached to the National Research Council, investigated the conversion and published his findings in Building Research Note #98- Converting Heating Degree-Days from Below 65°F to Below 18°C. The conversion takes the form shown below and is accurate to within 2 Celsius degree-days per month.

$$C_d = \frac{5}{9}(F_d - K)$$

F_d — is number of heating degree-days per month in Fahrenheit using 65°F as base temperature.

C_d — is number of heating degree-days per month in Celsius using 18°C as base temperature.

K — is a variable correction factor necessitated by the change in base temperature, and is selected from the following table reproduced from the D. W. Boyd paper.

Table 1

F_d	K	F_d	H
1 — 3	0	98 — 114	10
4 — 11	1	115 — 132	11
12 — 19	2	133 — 154	12
20 — 28	3	155 — 180	13
29 — 37	4	181 — 213	14
38 — 47	5	214 — 257	15
48 — 58	6	258 — 323	16
59 — 70	7	324 — 466	17
71 — 83	8	467 and up	18
84 — 97	9		

Examples:

To convert a monthly value of 148 heating degree-days based on 65°F to Celsius heating degree-days base on 18°C, proceed in the F_d column of the above table to 133 — 154 row. Select 12 from the K column and substitute in the above equation.

$$C_d = \frac{5}{9}(148 - 12)$$

C_d = 75.6 or 76 Heating degree-days based on 18°C.

If the value to be converted is 1254 heating degree-days on the Fahrenheit scale, the correction factor K is 18. The conversion then is

$$C_d = \frac{5}{9}(1254 - 18)$$

= 686.6 or 687 Heating degree-days based on 18°C.

Degree days and design temperatures for selected locations in Canada

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
British Columbia		
Abbotsford	−10	3150
Agassiz	−13	2960
Alberni	−5	3180
Ashcroft	−25	4060
Beatton River	−37	7010
Burns Lake	−30	5720
Cache Creek	−25	4080
Campbell River	−7	3200
Carmi	−24	5210
Castlegar	−19	3747
Chetwynd	−35	5890
Chilliwack	−12	2970
Cloverdale	−8	3030
Comox	−7	3203
Courtenay	−7	3250
Cranbrook	−27	4762
Crescent Valley	−20	4320
Crofton	−6	3140
Dawson Creek	−36	5890
Dog Creek	−28	5110
Duncan	−6	3200
Elko	−28	4900
Fernie	−29	4980
Fort Nelson	−40	7063
Fort St. John	−36	6119
Glacier	−27	5730
Golden	−28	4950
Grand Forks	−20	4050
Greenwood	−20	4520
Haney	−9	3280
Hope	−16	3150
Kamloops	−25	3756
Kaslo	−23	4110
Kelowna	−17	3680
Kimberley	−26	4890
Kitimat Plant	−16	4110
Kitimat Townsite	−16	4130
Langley	−8	2980
Lilooet	−23	4130
Lytton	−19	3220
Mackenzie	−35	5950
McBride	−34	5720
McLeod Lake	−35	5720
Masset	−7	3720
Merritt	−26	4190
Mission City	−9	2980
Montrose	−17	4080
Nakusp	−24	4130
Nanaimo	−7	3010
Nelson	−20	3920
New Westminster	−8	2930
North Vancouver	−7	3090
Ocean Falls	−12	3520
100 Mile House	−28	4900
Osoyoos	−16	3530
Penticton	−16	3514
Port Alberni	−5	3180
Port Hardy	−5	3661
Port McNeill	−5	3480
Powell River	−9	2900
Prince George	−33	5388
Prince Rupert	−14	4117
Princeton	−27	4560
Qualicum Beach	−7	3250
Quesnel	−33	4940
Revelstoke	−26	4073
Richmond	−7	2920
Salmon Arm	−23	4090
Sandspit	−6	3650
Sidney	−6	3090
Smithers	−29	5290
Smith River	−46	7610
Squamish	−11	3140
Stewart	−23	4710
Taylor	−36	5890
Terrace	−20	4430
Tofino	−2	3250
Trail	−17	3650
Ucluelet	−2	3250
Vancouver	−7	3007
Vernon	−20	4040
Victoria	−5	3076
Williams Lake	−31	5105
Youbou	−5	3360
Alberta		
Athabasca	−35	6280
Banff	−30	5719
Barrhead	−34	6000

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
Beaverlodge	−35	5820
Brooks	−32	5290
Calgary	−31	5345
Campsie	−34	6010
Camrose	−33	5720
Cardston	−30	4830
Claresholm	−31	5120
Cold Lake	−36	6450
Coleman	−31	5120
Coronation	−31	5906
Cowley	−31	5150
Drumheller	−31	5570
Edmonton	−32	5589
Edson	−34	5910
Embarras Portage	−41	7490
Fairview	−38	6170
Fort Saskatchewan	−32	5890
Fort Vermilion	−41	7170
Grande Prairie	−36	6145
Habay	−41	7050
Hardisty	−33	5950
High River	−31	5320
Jasper	−32	5532
Keg River	−40	6820
Lac La Biche	−35	6140
Lacombe	−33	5740
Lethbridge	−30	4718
McMurray	−39	6778
Manning	−39	6600
Medicine Hat	−31	4874
Peace River	−37	6424
Penhold	−32	5845
Pincher Creek	−32	5010
Ranfurly	−34	5980
Red Deer	−32	5700
Rocky Mountain House	−31	5550
Slave Lake	−36	6220
Stettler	−32	5590
Stony Plain	−32	5780
Suffield	−32	5360
Taber	−31	4750
Turner Valley	−31	5700
Valleyview	−37	6110
Vegreville	−34	6000
Vermilion	−35	6140
Wagner	−36	6180
Wainwright	−33	6000
Wetaskiwin	−33	5670
Whitecourt	−35	6130
Wimborne	−31	5620
Saskatchewan		
Assiniboia	−32	5340
Battrum	−32	5400
Biggar	−34	5890
Broadview	−34	6080
Dafoe	−36	6360
Dundurn	−35	5840
Estevan	−32	5542
Hudson Bay	−37	6470
Humbolt	−36	6280
Island Falls	−39	7100
Kamsack	−35	6290
Kindersley	−33	5710
Lloydminster	−35	6280
Maple Creek	−31	5180
Meadow Lake	−36	6550
Melfort	−37	6390
Melville	−34	6170
Moose Jaw	−32	5400
Nipawin	−38	6550
North Battleford	−34	6050
Prince Albert	−37	6562
Qu'Appelle	−34	6060
Regina	−34	5920
Rosetown	−33	5860
Saskatoon	−35	6077
Scott	−34	6260
Strasbourg	−34	5890
Swift Current	−32	5482
Uranium City	−44	8210
Weyburn	−33	5720
Yorkton	−34	6239
Manitoba		
Beauséjour	−33	5830
Boissevain	−32	5610
Brandon	−33	6037

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
Churchill	−39	9213
Dauphin	−33	6150
Flin Flon	−38	6780
Gimli	−34	6030
Island Lake	−36	7210
Lac du Bonnet	−34	5950
Lynn Lake	−40	7820
Morden	−31	5490
Neepawa	−32	5950
Pine Falls	−34	6000
Portage la Prairie	−31	5890
Rivers	−34	5940
St. Boniface	−33	5830
St. Vital	−33	5830
Sandilands	−32	5890
Selkirk	−33	5890
Split Lake	−38	7880
Steinbach	−33	5830
Swan River	−36	6280
The Pas	−36	6852
Thompson	−42	7930
Transcona	−33	5830
Virden	−33	5890
Whiteshell	−34	5950
Winnipeg	−33	5889
Ontario		
Ailsa Craig	−17	3980
Ajax	−20	4080
Alexandria	−24	4580
Alliston	−23	4520
Almonte	−26	4740
Ansonville	−33	6220
Armstrong	−39	6892
Arnprior	−27	4800
Atikokan	−34	6040
Aurora	−21	4300
Bancroft	−27	4960
Barrie	−24	4470
Barriefield	−22	4240
Beaverton	−24	4580
Belleville	−22	4190
Belmont	−17	3980
Bowmanville	−20	4130
Bracebridge	−26	4800
Bradford	−23	4410
Brampton	−19	4200
Brantford	−17	3920
Brighton	−21	4240
Brockville	−23	4300
Brooklin	−20	4240
Burks Falls	−26	5070
Burlington	−17	3700
Caledonia	−17	3920
Cambridge	−18	4130
Campbellford	−23	4410
Camp Borden	−23	4470
Cannington	−24	4580
Carleton Place	−25	4690
Cavan	−22	4470
Centralia	−17	3940
Chapleau	−35	5950
Chatham	−16	3530
Chelmsford	−28	5290
Chesley	−19	4240
Clinton	−17	4130
Coboconk	−25	4740
Cobourg	−21	4190
Cochrane	−34	6230
Colborne	−21	4190
Collingwood	−22	4580
Cornwall	−23	4470
Corunna	−16	3810
Deep River	−29	5180
Deseronto	−22	4080
Dorchester	−18	4030
Dorion	−33	5890
Dresden	−16	3700
Dryden	−34	6080
Dunbarton	−19	4030
Dunnville	−15	3810
Durham	−20	4620
Dutton	−16	3750
Earlton	−33	5866
Edison	−34	6000
Elmvale	−24	4580
Embro	−18	4130
Englehart	−33	5950
Espanola	−25	5070

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C
Exeter	−17
Fenelon Falls	−25
Fergus	−20
Fonthill	−15
Forest	−16
Fort Erie	−15
Fort Frances	−33
Gananoque	−22
Georgetown	−19
Geraldton	−35
Glencoe	−16
Goderich	−16
Gore Bay	−23
Graham	−37
Gravenhurst	−26
Grimsby	−16
Guelph	−19
Guthrie	−24
Hagersville	−16
Haileybury	−32
Haliburton	−27
Hamilton	−17
Hanover	−19
Hastings	−23
Hawkesbury	−25
Hearst	−34
Honey Harbour	−24
Hornepayne	−37
Huntsville	−26
Ingersoll	−18
Jarvis	−16
Jellicoe	−36
Kapuskasing	−33
Kemptville	−25
Kenora	−33
Killaloe	−28
Kincardine	−17
Kingston	−22
Kinmount	−26
Kirkland Lake	−33
Kitchener	−19
Lakefield	−24
Lansdowne House	−39
Leamington	−15
Lindsay	−24
Lions Head	−19
Listowel	−19
London	−18
Lucan	−17
Maitland	−23
Markdale	−20
Martin	−36
Matheson	−33
Mattawa	−29
Midland	−23
Milton	−18
Milverton	−19
Minden	−26
Mississauga	−18
Mitchell	−18
Moosonee	−36
Morrisburg	−23
Mount Forest	−21
Muskoka Airport	−26
Nakina	−35
Napanee	−22
Newcastle	−20
New Liskeard	−32
Newmarket	−22
Niagara Falls	−16
North Bay	−28
Norwood	−24
Oakville	−18
Orangeville	−21
Orillia	−25
Oshawa	−19
Ottawa	−25
Owen Sound	−19
Pagwa River	−34
Paris	−17
Parkhill	−16
Parry Sound	−24
Pembroke	−28
Penetanguishene	−23
Perth	−25
Petawawa	−29
Peterborough	−23
Petrolia	−16
Picton	−21

NCE ION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
ville	−18	4130
Alexander	−29	5180
pine	−34	6220
Burwell	−15	3810
Colborne	−15	3640
Credit	−18	3700
Dover	−15	3830
Elgin	−17	4240
Hope	−21	4190
Perry	−22	4410
Stanley	−15	3810
ott	−23	4350
eton	−17	4030
	−35	6060
Lake	−34	6220
ew	−27	4790
way	−15	3590
and	−26	4800
atharines	−16	3550
arys	−18	4130
homas	−16	3850
a	−16	3840
Ste. Marie	−25	5180
iber	−35	6070
rth	−17	4240
oe	−17	3962
Lookout	−34	6180
s Falls	−25	4520
ville	−16	3920
th Rock Falls	−34	6280
ampton	−17	4250
Porcupine	−34	6220
River	−27	5180
ng	−23	4340
ord	−18	4300
roy	−17	3920
sville	−18	4080
on Falls	−27	5180
y	−28	5447
dge	−27	5120
ock	−18	4190
esford	−18	4030
ord	−16	3860
der Bay	−31	5746
nburg	−17	3920
gami	−30	5570
ins	−34	6189
nto	−18	4082
on	−21	4116
Creek	−27	5230
Lake	−38	7680
dge	−22	4450
er	−25	4690
ria	−15	3860
erton	−18	4160
ceburg	−16	3620
rloo	−19	4110
ord	−16	3810
a	−35	5640
nd	−15	3640
Lorne	−16	3750
oy	−20	4080
e River	−39	6380
ton	−18	4412
sor	−16	3590
ham	−18	4240
dstock	−18	4100
ning	−16	3810
n Vale	−24	4690
	−30	5830
	−34	6300
nne Lorette	−25	5110
a	−29	5740
tos	−26	4800
er	−25	4740
ville	−31	5776
Comeau	−27	5981
nsfield	−23	4470
port	−25	4850
rd	−23	4470
il	−24	4580
ard	−24	4520
ingham	−26	4900
na	−25	5400
ell's Bay	−28	4850
Valcartier	−25	5120
utimi	−30	5510

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
Coaticook	−24	5010
Contrecoeur	−24	4800
Cowansville	−24	4580
Dolbeau	−31	5950
Dorval	−23	4470
Drummondville	−25	4740
Farnham	−24	4590
Fort Chimo	−39	8460
Fort Coulonge	−28	4850
Gagnon	−33	7490
Gaspé	−23	5340
Gatineau	−25	4740
Gentilly	−25	4850
Gracefield	−28	5070
Granby	−25	4580
Great Whale River	−36	8133
Harrington Harbour	−25	6110
Havre St. Pierre	−27	6110
Hemmingford	−23	4580
Hull	−25	4740
Iberville	−24	4630
Joliette	−25	4880
Jonquière	−29	5720
Kenogami	−29	5730
Knob Lake	−38	8229
Knowlton	−24	4630
Kovik Bay	−38	9550
Lachine	−23	4470
Lachute	−25	4850
Lafleche	−24	4520
La Malbaie	−26	5340
La Salle	−23	4470
La Tuque	−29	5350
Laval	−24	4580
Lennoxville	−28	4850
Léry	−23	4520
Les Saules	−25	5010
Lévis	−25	4900
Loretteville	−25	5120
Louiseville	−25	5010
Magog	−26	4730
Malartic	−33	6110
Maniwaki	−29	5319
Masson	−26	4850
Matane	−24	5400
Mégantic	−27	5280
Mont Joli	−24	5353
Mont Laurier	−29	5340
Montmagny	−25	4900
Montreal	−23	4471
Montreal Nord	−23	4470
Mount Royal	−23	4470
Nitchequon	−38	7880
Noranda	−33	6220
Outremont	−23	4470
Percé	−22	5290
Pierrefonds	−23	4470
Pincourt	−23	4520
Plessisville	−26	5120
Pointe Claire	−23	4470
Pointe Gatineau	−25	4740
Port Alfred	−29	5720
Port Cartier	−29	6000
Port Harrison	−38	9070
Preville	−24	4520
Québec	−25	5080
Richmond	−25	4740
Rimouski	−25	5400
Rivière du Loup	−25	5533
Roberval	−30	5740
Rock Island	−24	4900
Rosemere	−24	4580
Rouyn	−33	6220
Ste. Agathe des Monts	−27	5380
Ste Anne de Bellevue	−23	4520
St. Canut	−25	4900
St. Félicien	−31	6000
Ste. Foy	−25	4900
St. Hubert	−24	4540
St. Hubert de Témiscouata	−26	5780
St. Hyacinthe	−24	4650
St. Jean	−24	4630
St. Jérôme	−25	5060
St. Jovite	−27	5290
St. Lambert	−23	4470
St. Laurent	−23	4470

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
St. Nicolas	−25	4850
Schefferville	−38	8229
Senneterre	−34	6220
Seven Islands	−30	6135
Shawinigan	−26	5110
Shawville	−27	4850
Sherbrooke	−28	5242
Sillery	−25	4900
Sorel	−24	4840
Sutton	−24	4690
Tadoussac	−26	5380
Temiscaming	−30	5220
Thetford Mines	−26	5350
Three Rivers	−25	5070
Thurso	−26	4850
Val d'Or	−33	6146
Valleyfield	−23	4520
Varennes	−24	4630
Verchères	−24	4740
Verdun	−23	4470
Victoriaville	−26	5040
Ville d'Anjou	−23	4470
Ville Marie	−31	5760
Waterloo	−24	4580
Westmount	−23	4470
Windsor Mills	−25	4630
New Brunswick		
Alma	−21	4580
Bathurst	−23	5160
Campbellton	−26	5100
Chatham	−24	4884
Edmundston	−27	5340
Fredericton	−24	4699
Gagetown	−23	4490
Grand Falls	−27	5250
Moncton	−22	4709
Oromocto	−23	4740
Sackville	−21	4590
Saint John	−22	4771
St. Stephen	−22	4580
Shippigan	−22	5180
Woodstock	−26	4770
Nova Scotia		
Amherst	−21	4580
Antigonish	−20	4580
Bridgewater	−15	4190
Canso	−17	4410
Dartmouth	−16	4200
Debert	−22	4580
Digby	−15	3850
Greenwood	−17	4130
Halifax	−16	4123
Kentville	−18	4240
Liverpool	−14	4010
Lockeport	−14	3980
Louisburg	−15	4410
Lunenburg	−15	4190
New Glasgow	−21	4580
North Sydney	−16	4410
Pictou	−21	4580
Port Hawkesbury	−19	4470
Springhill	−20	4580
Stewiacke	−21	4520
Sydney	−16	4459
Tatamagouche	−21	4580
Truro	−21	4704
Wolfville	−19	4300
Yarmouth	−13	4024
Prince Edward Island		
Charlottetown	−20	4623
Souris	−19	4580
Summerside	−20	4600
Tignish	−20	4850
Newfoundland		
Argentia	−13	4600
Bonavista	−17	5010
Buchans	−21	5530
Cape Harrison	−29	6880
Cape Race	−14	5010
Corner Brook	−19	4900
Gander	−18	5039
Goose Bay	−31	6522
Grand Bank	−14	4560
Grand Falls	−21	5100
Labrador City	−35	7770
Port aux Basques	−15	4800

PROVINCE AND LOCATION	JANUARY DESIGN TEMPERATURE 2½% °C	DEGREE DAYS BELOW 18°C
St. Anthony	−24	5940
St. John's	−14	4804
Stephenville	−17	4783
Twin Falls	−35	7820
Wabana	−15	4850
Wabush Lake	−35	7770
Yukon Territory		
Aishihik	−44	8070
Dawson	−50	8274
Destruction Bay	−43	7820
Snag	−51	8640
Teslin	−41	7050
Watson Lake	−46	7510
Whitehorse	−41	6879
Northwest Territories		
Aklavik	−44	9890
Alert	−43	12930
Arctic Bay	−43	11510
Baker Lake	−45	10870
Cambridge Bay	−45	11900
Chesterfield Inlet	−40	10750
Clyde	−41	10930
Coppermine	−44	10700
Coral Harbour	−41	10690
Eskimo Point	−40	9990
Eureka	−47	13340
Fort Good Hope	−46	9340
Fort Providence	−44	8020
Fort Resolution	−42	8100
Fort Simpson	−45	8020
Fort Smith	−43	7852
Frobisher Bay	−40	9845
Hay River	−41	7950
Holman Island	−43	10950
Inuvik	−46	10174
Isachsen	−46	13360
Mould Bay	−45	12990
Norman Wells	−46	8830
Nottingham Island	−38	9720
Port Radium	−44	9170
Rae	−44	8660
Rankin Inlet	−40	10600
Resolute	−44	12549
Resolution Island	−35	8780
Tungsten	−49	8770
Yellowknife	−43	8593

Financial analyses

The nine other booklets in this series contain suggestions for energy savings which will require the investment of capital dollars in order to achieve savings. In some cases, the savings per year may be so large, and the capital cost so small, that the desirability of the project is obvious. In other cases, a more detailed analysis is needed.

In all cases, it is dangerous to reject a program on the basis of a simple "payback" analysis.

In some companies the rule is that any project with a capital requirement of, say, $25,000 or more requires a detailed rate of return analysis— complete with provisions for "discounted cash flow". Projects worth less than this amount can be justified on the strength of simple "payback" analysis.

This approach has two pitfalls:

1. A simple payback analysis will not take into account many factors which could make the energy conservation project appear more attractive than other capital projects competing for top management approval.
2. Performing a more detailed analysis forces the proponent department or manager to fully understand the project and to be better able to defend it orally, should this be necessary, at a management meeting.

This section discusses two of a number of procedures for making a financial analysis of cost saving opportunities. An important factor in the analysis is the amount you are paying for your energy.

The reason for determining energy costs is to allow you to make valid analysis of the actions you might need to take to save energy and money, The cost varies widely with the fuel source used. The following table shows the cost of energy at various fuel and electricity prices.

TABLE 1

Fuel or Electricity Prices

Electricity, $/kWh	Oil, $/gal	Gas, $/Mcf	Propane, $/gal	Coal $/ton	Resulting Energy Cost, $/MMBtu*
0.0034	0.168	1.00	0.1104	24.00	1.00
0.0051	0.252	1.50	0.1656	36.00	1.50
0.0068	0.336	2.00	0.2196	48.00	2.00
0.0077	0.378	2.25	0.2484	54.00	2.25
0.0085	0.420	2.50	0.2760	60.00	2.50
0.0094	0.462	2.75	0.3036	66.00	2.75
0.0102	0.504	3.00	0.3300	72.00	3.00
0.0119	0.588	3.50	0.3864	84.00	3.50
0.0136	0.672	4.00	0.4392	96.00	4.00
0.0171	0.84	5.00	0.5496	120.00	5.00
0.0239	1.176	7.00	0.7692		7.00
0.0341		10.00			10.00
0.0512					15.00
0.0682					20.00

*MMBtu equals one million Btu's

Benefit/Cost Analysis.

The benefit/cost analysis can be used to decide if a capital investment is economically justified, or it can be used as a basis to choose between several alternatives after a decision to invest has been made. First, all benefits and all costs are reduced to a dollar value, and the ratio of benefits to costs is taken. If the ratio is greater than unity, the project may be economically justified and should be more fully examined.

Example - a heat recovery unit for a small heat treating plant costs $55,000 installed. It is estimated that the unit will save $12,000 annually in fuel and have a life of 10 years. Annual maintenance costs will be $500. The benefit/cost ratio is determined as follows:

Benefits = $12,000 − $500 = $11,500 per year.

Costs: Assume money is available at 10% interest, the annual cost will be the amortization cost, or annual payment required to repay the debt at 10% interest in 10 years. This is found by multiplying the total loan by a capital recovery factor, F, as found in Table II. Thus, for an interest rate of 10% for 10 years, F = 0.1628, and cost = $55,000 x 0.1628 = $8,954 and, Benefit/Cost ratio = $11,500/$8,954 = 1.28

The investment is profitable since the benefit/cost is larger than unity.

TABLE II

Capital Recovery Factor - F

Yrs.	Interest Rate				
n	6.0%	7.0%	8.0%	10.0%	12.0%
5	0.2374	0.24389	0.25046	0.26380	0.27741
10	0.1359	0.14238	0.14903	0.16275	0.17698
15	0.10303	0.10979	0.11683	0. 13147	0.14682
20	0.0872	0.09439	0.10185	0.11746	0.13388
25	0.0782	0.08581	0.09368	0.11017	0.12750
30	0.0726	0.08059	0.08883	0.10608	0.12414
40	0.0665	0.07501	0.08386	0.10226	0.12130

Example — It has been decided by a small manufacturing company to make a capital investment in a waste-water, heat recovery unit. Two systems are available:

System - A:

Total Cost	$14,000
Annual operation and maintenance costs	$ 900

System - B:

Total Cost	$12,000
Annual operation and maintenance costs	$ 1,400

Both systems reduce energy utilization by the same amount, and both systems have estimated lives of 15 years. Money is available at 10%.

Which system should provide the greater long term savings? Net Benefit per year of System - A over System - B - $500. Additional cost of System - A over System - B = $2,000. For 10% interest rates over 15 years, the capital recovery factor, is F = 0.1315 (from Table II). Thus, the cost per year for the additional $2,000 of capital investment is:

Cost = $2,000 x 0.1315 = $263.
and
Benefit/cost = $500/$263 = 1.90

Although the original cost of System - A is 16.7% more than System - B, System - A will provide the greater long term savings over the life of the system.

Time to Recoup Investment (Payback)

Another approach is to determine how long it will take to recoup the investment required to accomplish a particular energy (dollar) savings. It is assumed that the annual savings is used to pay off the required loan at the current interest rate. If the investment is recouped in a period less than the life of the equipment, the investment is considered profitable. Table III can be used to estimate the "time to recoup investment".

TABLE III

Years to Recoup Investment

Investment/	Interest Rate			
Savings Ratio	6%	8%	10%	12%
2	2.19	2.27	2.34	2.42
3	3.41	3.57	3.74	3.94
4	4.71	5.01	5.36	5.77
5	6.12	6.64	7.27	8.08
6	7.66	8.50	9.61	11.2
7	9.35	10.7	12.6	16.2
8	11.2	13.3	16.9	28.4

Example — It has been estimated that an investment of $22,500 is required to update the air-conditioning and heating system equipment and controls installed in an older five-story office building. The life of the system will be extended for ten years. The annual savings in energy purchased, plus reduced maintenance cost should be approximately $5,500. Money is available at 10% interest. To find the time to recoup the investment the following ratio is calculated:

Capital investment/annual savings = $22,500/$5,500 = 4.09

Referring to Table III, at an investment/savings ratio of 4, and an interest rate of 10%:

Time to recoup investment = 5.36 years

This is less than the extended life of the system, and so the investment would be profitable.

These examples of cost analysis do not, of course, take into consideration important considerations such as "opportunity cost" (the value of the money spent if it were to be spent in some other way), or the impact of the provincial and federal taxes.

It is recommended that, if an investment of any significant size is being considered, a more detailed analysis of the life-cycle costs be carried out.

Abbreviations

A	ampere
ac	alternating current
MMM	billion
MMM Btu	billion Btu
bhp	brake horsepower
Btu	British thermal unit
C	degree Celsius (Centigrade)
cfm	cubic feet per minute
cu ft	cubic feet
d	day
dc	direct current
eff	efficiency
°F	degree Fahrenheit
fpm	foot per minute
ft	foot
gal	gallon
gpm	gallons per minute
h	hour
hp	horsepower
i.d.	inside diameter
in	inch
M	thousand
Mcf	thousand cubic feet
KVA	kilovolt ampere
kVAR	kilovolt ampere reactive
Kw	kilowatt
Kwh	kilowatt hour
lb	pound
ln	logarithm (natural)
MM	million or mega
MMBtu	million Btu
min	minute
mo	month
o.d.	outside diameter
oz	ounce
PF	power factor
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
q	rate of heat transfer (Btu/h)
ROI	return on investment
rpm	revolutions per minute
sec	second
sat	saturated
sq ft	square foot
std	standard
t	temperature
V	volt
W	watt
wk	week
yr	year
$\triangle$	delta or difference

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SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK)= 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1^\circ = (\pi/180)$ rad
minute (of arc)	′	1 ′ = (π/10 800) rad
second (of arc)	″	1 ″ = (π/648 000) rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY IN HEATING COOLING AND LIGHTING

2

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Office of Energy Conservation
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SAVING MONEY IN HEATING COOLING AND LIGHTING 2

Saving Money in Heating, Cooling and Lighting

Introduction:

Heating, cooling and lighting industrial buildings offers a major potential energy savings to Canadian industry.

This booklet is provided in the hope that it may make plant management more aware of the available opportunities and offer some assistance in putting these programs into practice.

While the booklet is relatively self-contained, some information related to heating buildings with waste heat can be found in other booklets in this series. An examination of the master index in booklet I is recommended.

Heating, Ventilation and Air Conditioning

Over a period of several centuries buildings have evolved from simple shelters which provided the minimum requirements of safety and isolation from a sometimes hostile external environment into very complex systems intended to satisfy many physiological and psychological needs. This evolution has assured building occupants greater comfort and a more productive working environment. However, these improvements have not come without significant costs. More than one third of Canada's energy is consumed in residential and commercial buildings, unfortunately much of it needlessly. Recent studies have demonstrated that with proper design, operation, and maintenance industrial buildings can provide safe, healthful, and comfortable environments at levels much lower than present energy consumption.

In establishing an energy management program for buildings the first step is to determine the present operating characteristics and energy use of the building. The next step is to evaluate how much energy should actually be required to maintain comfort within the building. This is accomplished by first calculating the buildings' heating and cooling loads and then determining the energy required by the heating ventilating and air conditioning system to meet these loads during occupied periods. Usually the actual energy consumption is considerably greater than that required to serve the intended function of the building. The final step is to bring the actual consumption into line with that required.

The process of evaluating the energy required to operate a building is somewhat more complicated than assessing the actual energy consumption. However, the data collected for the building and systems profiles and energy audit (see Booklet 1 in this series) provide the basis for both calculations. Either computerized or hand calculation procedures can be used. Although the computerized analyses provide more accurate information and allow consideration of a greater number of conservation options, they are by no means a necessity.

Building heating and cooling loads are influenced by:

- Heat transfer through the building envelope
- The introduction of ventilation air and/or infiltration
- Internal heat generated by the lights, equipment, and people within the building.

The size, function, and number of hours the building is operated have a significant influence on the relative magnitude of each of these energy components. The loads in high-rise commercial buildings and retail establishments are primarily due to internal loads and ventilation requirements. On the other hand, suburban low-rise plants and offices tend to be strongly influenced by environmental factors which control heat gain or loss through the building envelope and by infiltration.

Although general guidelines for annual per square foot energy consumption — or energy budgets — can be established as targets, it must be recognized that all buildings are different and their individual physical and operational characteristics result in varying energy requirements.

Appropriate energy management requires a

building-by-building analysis including the following:

1. Gathering pertinent climatic data.
2. Describing the thermal characteristics of the building.
3. Evaluating internal and environmental loads.
4. Determining building and system operating schedules.
5. Relating building energy requirements to heating and cooling loads and operational schedules to energy requirements.

Frequently the process of gathering this information will bring to light a number of areas where the building not only has not been optimized in terms of energy consumption, but is not even operating as originally designed. For example: system controls which are out of adjustment or entirely inoperable; equipment such as cooling towers, condenser coils, filters, and air dampers which have not been maintained; and air distribution systems which are out of balance. Each of these could create a situation in which the HVAC system would use considerably more energy than if it were operating as the designer intended it to. The ultimate result — increased energy consumption.

Reducing heat loss and gain — the common ground.

Perhaps the best common ground from which to start on this analysis is the subject of reducing heat losses. After all, it matters not whether the building is being heated on a 20-degree below zero day in January or cooled from a sweltering 90°F day in August, the fundamental basis for an efficient system is to minimize the amount of warm air leaving or cool air that enters the building. And there are a number of ways in which this can be done.

The line of first defence should come as no surprise to any manager who has been concerned with energy around his own house over the past few years. The answer is to first seal up any cracks around doors and windows and, for example, between exterior concrete panel joints. There are a number of products that can be used for this purpose, but most are very similar to the varieties of household caulking that have been used for years around homes to seal out winter drafts.

Following this parallel, most homes do not need to worry about replacement of broken windows or about closing windows during the heating season. No homeowner conscious of his comfort (or his fuel bill) would allow either one of these things to go on in the winter. But in industrial plants it frequently is a problem and one that should be remedied as soon as possible.

Many plants have done away with the problem of broken windows or air leaks around windows in a very direct fashion — they have done away with the windows. And where they are not needed, this is frequently a very effective way of minimizing heat loss.

This fact is particularly true with older industrial buildings equipped with skylights. Not only do they represent a major source of heat loss, they incur a major maintenance cost and should be eliminated.

Certainly, for any new industrial building, the use of glass should be avoided wherever possible — and double glazing should be specified for new or retrofit installations. In fact in some situations double glazed windows with proper orientation and slant can represent a heat gain during cold weather.

In older buildings where double glazing is impossible it may prove feasible to install storm windows on either the inside or the outside.

The problem of open windows in winter generally applies to plants which generate a great deal of process heat. And here other solutions such as shutting off as many sources of heat as possible or insulating process tanks or piping (discussed in the "Process Design" handbook).

Another major source of infiltration of outside air are open loading dock doors. Answers include building a barrier to isolate loading dock areas — providing either no heat or infra red heating, erection of canvas or plastic curtains around the loading dock and the use of bumpers or other door seals to effect a better seal between the truck trailer and the loading door. All are considered more fully in the handbook on Transportation in this series.

But loading dock doors are not the only problem area. Any door will do. And construction of

entrances in vestibules deep enough to prevent anyone from holding inside and outside doors open at the same time is generally quite effective at minimizing infiltration.

Solar heat gain — a significant factor.

During the cooling season, significant extra load is placed on air conditioning systems by solar gains if measures are not taken to control it. No less importantly, already uncomfortable conditions in industrial buildings which are not air conditioned may be made even more uncomfortable.

Oddly enough, the roof and not the windows of most buildings is the largest source of heat gain. And many of the comments that apply to insulation of the roof area — particularly in raising the reflectivity of the conventional pitch black roof — will apply.

As with use of water as a roof insulating medium, care should be taken to avoid the many problems that can result from water ponding. However, there are roof cooling spray nozzle systems available that avoid any problems of water build-up and, at the same time, provide the greatest possible insulation against incursion of solar heat.

According to one manufacturer, evapourative roof cooling using a spray nozzle will reduce 10 Btu's of heat gain through a given roof to 0.9 Btu. On a comparative basis, a 6-inch-deep pool of water will reduce the same 10-Btu heat penetration to 1.4 Btu. On hot sunny days (particularly with low humidity), it is estimated that the effect could be to reduce indoor temperatures by as much as 15°F — without the use of any internal air conditioning. An ancillary benefit is that roofs may last longer due to reduced evaporation of volatile oils and minimized thermal expansion stresses.

Windows are also a major source of solar heat gain. Here, there are a number of potential solutions. The most basic of these is to adjust existing blinds, drapes, shutters or other shading devices to prevent entry of solar radiation into the building. However, there is a potential trade-off here if shading conflicts with requirements to use natural light as a source of illumination. (An analysis of relative energy consumption due to solar radiation loads versus artificial illumination loads may be required.)

Where blinds or drapes do not exist, they may well be economically justifiable on south, east and west facing windows which are subject to direct sunlight in hot weather and/or exposed to a large expanse of sky.

Lightweight drapes with reflective properties are effective, as are vertical or horizontal reflective blinds (often made of PVC). Vertical louvers are generally most effective on the west and east sides of a building — horizontal blinds on the south side. Where drapes are used, fire codes should be checked before choosing a material.

Reflective film coatings or tinted glass may also be a good investment for all windows except those with a northern exposure. Reflective sheets of varying reflectance values and thicknesses are available from a number of manufacturers at relatively low cost. Not only do they help control solar radiation, they may increase the strength, resistance and impermeability of window surfaces. Depending on colour, quantity and make, the films allow a maximum heat transmission of from 55 to 90 Btu/hr/sq foot. In comparison, the maximum heat transferable through a clear single pane of glass is 260 Btu/hr/sq ft.

The films transmit 9 to 33 percent of the visible light spectrum and reflect 5 to 75 percent of the solar radiation which strikes them. For example, reflective coating on glass on the south, east or west side of a building that reduced solar radiation by 50 percent could save from 30,000 to 50,000 Btu's/sq ft (window) per season, in hot weather, for energy required for space cooling. As a result, the cooling load can be reduced by about 3 ton-hours per sq ft of glass per year by proper use of shading devices. (See case history section for example).

Where glass is being replaced, "environmental" glass with reflective properties should be considered. Available in single or double panes, tinted glass can cut transmission of incident solar radiation in half, (from 90 to 45%). They are, however, not as effective as reflective films (which can, apparently, lower levels to 20%).

It should also be remembered that skylights on a roof transmit between two and four times as much solar heat in the summer time as an equal area of east or west facing glass. Where total replacement cannot be justified, exterior controls such as white paint can be used. As an alternative, interior shades with reflective

coatings can reduce solar heat gain in the summer by up to 80 percent.

A final thought on solar heat gain pertains to the location of condenser coils for air conditioning equipment. If they are located in direct sunlight, they are affected by solar heat and their effectiveness is decreased, To combat this, where possible, they should be located on the north side of the building and if at ground level they should be shaded by shrubs or some sort of sun shield. Roof-top units should also be protected by sun shields wherever possible.

Reducing internal heat gain in summer.

Obviously, infiltration and solar heat gain are not the only source of extra load on an air conditioning system. A major factor which must be considered is "internal heat gain", in short, the sources of heat from within the plant that can be controlled. Obvious sources of this internal heat are excessive lighting levels, inefficient fixtures which produce "more heat than light", miscellaneous motors and combustion equipment, process tanks and virtually any other source of heat in the plant which can be reduced, or eliminated.

Among the basic solutions to excessive cooling loads on air conditioning equipment are the following:

- install heat shields around ovens and other heat producing equipment.
- insulate steam and hot water pipes and hot air ducts
- reduce usage and idling time of motors and combustion equipment
- insulate tanks and process equipment
- isolate and exhaust heat from process ovens and kilns whenever enthalpy of outdoor make up air is lower than the enthalpy of the space
- adjust reheat systems using hot and cold mixing boxes or electric duct heaters
- turn off unnecessary lighting. Replace inefficient lighting sources.

It goes without saying that the question of internal loads is a "two edged sword". The two areas or "heating" and air conditioning cannot be isolated. For example, process heat which is exhausted during the summer, should be used in whatever way possible as a source of energy in the winter. If the process requires a large volume of exhaust air, the possibility of purification of air for re-entry into the building should be investigated. If this is not feasible, consideration should be given to a heat exchanger (see "Process Design" booklet) to pass heat on to building make-up air.

One source of waste heat which is not often utilized is that from large computer installations. A similar source of "free" heat during the winter can be obtained from air cooled compressors.

Facility usage — using the space more wisely.

One other avenue to controlling internal building loads is an examination of the manner in which the facility is being used. There may be many areas, in fact, where the personnel population allows for reduced lighting levels and lower heat or air conditioning levels.

One example worthy of note concerns an entire warehouse area that was kept at 70°F under winter conditions, because two warehouse men worked in the area. A survey showed that a great percentage of their time was spent doing paperwork — and as a result, a small office area was constructed for their use. The temperature was reduced to 55°F — and the savings were considerable.

Using another tack, changing the building — in this case installation of a drop ceiling to improve lighting levels and reducing the volume of conditioned air required — can often yield results.

There may even be areas where consolidation of personnel can be accomplished to reduce the total area to be conditioned. There are many possibilities, but each is directly dependent on local plant conditions — and may be turned up by a comprehensive energy audit.

Minimize air exhaust.

Assuming that obvious sources of heat gain and loss have been eliminated, the next most obvious step is to assure that the amount of air being exhausted to the atmosphere is being kept to an absolute minimum. Obviously, a sufficient number of air changes must occur so that air quality does not suffer but, frequently far more air is exhausted than needs to be, particularly in winter. The result is a greater than necessary energy consumption — and no appreciable change in plant air quality.

In fact, excessive ventilation is one of the biggest energy wasters of the list. Many codes require as much as 10 cfm per person of outside air — air that often has to be heated or cooled, humified or dehumified, cleaned, deodorized and moved.

In submarines, for example, as little as 1 cfm per person is considered acceptable. And in many industrial situations its quite possible that 5 cfm per person is feasible — a 50% cut. In one U.S. plant just a 10% reduction saved 1,740,000 Btu's a year per 1,000 cfm of system capacity. Local authorities should be consulted first, but in many cases conditional approval is granted on the basis that the system can easily be returned to the original volume should the reduced air intake prove unsatisfactory.

One option which should be investigated is the use of activated carbon filters for plant air. These can reduce intake of outside air, and, as a result heating and cooling costs.

Excessive ventilation creates a "negative pressure" within the building, a malaise whose first symptom is a difficulty in opening outside doors of the plant. Aside from the discomfort of excessive drafts, lower relative humidity and inconsistent heating levels around the plant, negative pressure simply means that excessive amounts of cold air is going to come in from the outside — and be heated. Make-up air in correct volumes has to come in from outside anyway — why not being it under control?

Insulation — reducing conductive heat loss and gain.

The major means of assuring that heat and cold remains inside as long as possible involves the use of insulating material for both walls and roofs. While the concepts and technology involved here are not complex, the array of products available as insulating media can appear quite confusing. As can the wide range of claims of potential savings made by some distributors and contractors.

By and large, though, the concept of insulation is a simple one. Of six common types of insulation, each has its inherent advantages and disadvantages. But a common standard of measuring their effectiveness as barriers to heat loss enables a simple economic analysis to be

Insulation Comparison

	Material	Location	Method of attachment	R (@ 75°)	Cost $/S.F.	Advantages	Disadvantages
1.	1″ Urethane Max. T. = 4″	Walls	Adhesive	6	Ins. .65 F.P. 1.70 $2.35	Most Efficient. Light Weight.	Highly Fammable — Must Be Fire Protected. Loses Insulation Value With Age "Grows" Under Conditions Of Humid Aging.
2.	1″ Polystyrene Board Max. T. = 3″	Walls	Adhesive	5	Ins. .55 F.P. 1.70 $2.25	Efficient. Light Weight. Moisture Resistant	Flammable — Must Be Fire Protected.
3.	1″ Isocyanurate Max. T. = 1½″	Walls	Spray	6	.90	Highly Efficient. Conforms To Irregular Surfaces.	Max. 30′ High Requires Bldg. Sprinklers.
4.	1¼″ Cellulose Max. T. — 1½″	Walls Ceilings	Spray	5.6	.70	Fire Resistive. Conforms To Irregular Surfaces. High Sound Absorbtion.	Friable. Poor Appearance. Cannot Apply At Temperatures Below 35°. May Sag When Ceiling Applied.
5.	3½″ Foil Reinforced Kraft Faced Fiberglass Blanket Only T. = 3½″	Walls Ceilings	Stick Clips, Weld Pins	11	.60	Fire Resistive. Easily Repaired Readily Cut To Fit Around Obstructions	Poor Appearance.
6.	1″ Foil Reinforced Kraft Faced Fiberglass Board — 6 P.C.F. Max. T. = 2″	Walls Ceilings	Adhesive Stick Clips Weld Pins	4.5	.70	Fire Resistive. Easily Repaired. Attractive Appearance.	Requires Careful Fitting Around Obstructions.

carried out to determine what results will be obtained, before insulation is installed.

This measure, of course, is the R factor. Mathematically, it's the reciprocal of "C" — "the amount of heat transmitted through one square foot of a stated thickness of homogenous material in one hour when a temperature difference of 1°F exists between the two surfaces of the material"

When used in conjunction with figures for the size of the building to be insulated; labour, material and energy costs; and a number representing the severity of the climate, it enables rudimentary calculations to be done that determine the cost effectiveness of insulation installations.

Before calculating the energy savings possible through insulation on a given roof, perhaps two points of explanation are in order. First, the total R factor is the sum of all R factors for different materials in a given wall or ceiling and in calculations, "U" — the reciprocal of total "R" is generally used as a measure of heat loss per hour. Secondly, while the concept of degree days is discussed in some detail in the guidebook and Index — along with a table of values for selected Canadian centres, a word of explanation is in order.

In essence, the degree day method is a simplified means of determining the outside temperature during the heating season for heat transfer calculations and is based on an average temperature of 65°F. On a given day, for every degree that the mean daily temperature falls below 65°F, there are an equivalent number of degree days. For example, if on January 25, the high was 24°F and the low 8°F, the number of degree days equals:

$$65 - \frac{(24 + 8)}{2} = 49 \text{ degree days.}$$

Applying these concepts to the actual calculation of a heat loss through an uninsulated built-up metal deck roof with a 8,000 degree day (°F) heating season:

Resistance to Heat Flow Up (Heating Season) (°F)

1.)	Outside film (15 mph Wind)	R = 0.17
2.)	Inside film	R = 0.68
3.)	Built-Up Roofing	R = 0.33
4.)	No Insulation	R = 0.00
5.)	Metal Deck	R = 0.61
	Total	R = 1.79

$U = 1/R = 1/1.79 = 0.56 \text{ Btu}/(\text{ft.}^2)(\text{Hr.})(°\text{F})$

$HL = (0.90 \text{ Btu}/\text{ft.}^2 - \text{hr} - °\text{F})(24 \text{ hr}/\text{day})(8{,}000\ °\text{F} - \text{days})$

$= 107{,}520 \text{ Btu}/\text{ft.}^2$ Per Heating Season

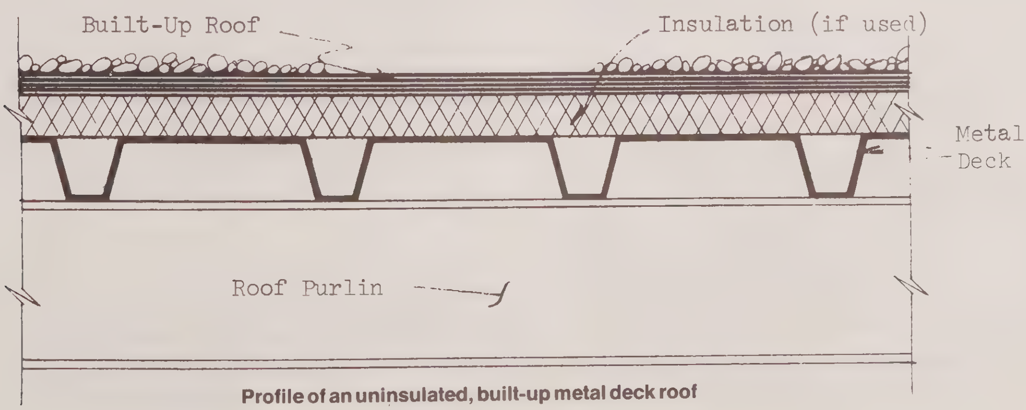
Given a 50,000 square foot roof on the plant and a cost of natural gas as a heating fuel of $2.00 per Mcf, the dollars consumed by this heat loss are:

$$\frac{107{,}520 \text{ Btu/sq. ft.} \times 50{,}000 \text{ sq. ft.} \times \$2.00/\text{Mcf}}{1{,}000{,}000 \text{ Btu/Mcf}}$$

= $10,752 per heating season

You can take this calculation one step further and determine the comparable heat loss and fuel consumption assuming a given level of insulation. The comparison derived often provides a solid economic rationale for the addition of insulation to existing facilities.

Even if a company has satisfied itself at one time or another over the last few years that insulation could not be justified because of cost, the increase in energy prices may well have swung the balance in favour of insulation. With all indications that the energy escalation will continue, any economic analysis which attempts



Profile of an uninsulated, built-up metal deck roof

to justify or disqualify insulation investments should take into account the effects of inflation on energy costs — not only will it affect the justification of insulation, it can affect the selection of the right type or thickness of insulation.

In addition, it's important to try not to let some of the time honoured arguments against insulation get in the way. One of the most frequent of these is that one of the walls in the plant is temporary "to allow for expansion" and, therefore, cannot be insulated. Experience has shown that expansion rarely comes when it is planned for, and as a result these companies sustain major energy losses for year after year until expansion comes along. In many cases the company expands by opening a new branch plant somewhere else and the insulation job simply doesn't get done.

If plans call for an expansion in five years and the insulation will pay for itself in a year and a half, it's still a good investment in energy conservation — even if construction does take place on schedule.

As a suggestion, keep abreast of what's happening in the field of insulation. For example, urethane foam roofing systems (see case history) are beginning to come into their own as a means of re-roofing and insulating at the same time and at a relatively low price. The fight for energy conservation is an ongoing one. Try to keep well armed with the latest in ammunition.

(It is worth stressing that any insulation selected should meet all established criteria regarding fire protection.)

Modification and maintenance.

With the plant well insulated and relatively free from unnecessary heat loss, the next logical line of defense is maintenance and modifications to the existing heating and air conditioning systems — again, designed to promote efficiency of operation and reduce energy consumption.

One author has called it the challenge of taking care of the "four simple **C**'s":

1. **C**heck system components
2. **C**lean filters, coils fan blades and housings
3. **C**alibrate controls
4. **C**ontrol energy consumption to maintain comfort with minimum energy use

All of it, some of it, or none of it can be done internally — depending upon the capabilities of the staff maintenance department. There are full or partial service companies who can do the things you can't do yourself.

Before doing anything else, it is necessary to check out the system. Look for worn or corroded components or gross irregularities like jumped switches and bypassed control valves.

Check for leaking dampers in the ventilating system. The system may be heating or cooling a surprising amount of unnecessary outdoor air — in some cases 15 or 20 percent more air than needed day and night.

Fans, belts, housings, filters and ducts should also be checked. Fan systems should be clean, tight and smooth running. For that matter, filters are probably the most important aspect of an air handling system. Certainly, clogged and dirty filters are one of the largest sources of energy waste in a HVAC system. Estimates as to the savings possible through keeping the filters clean range from three percent to as high as 10 percent. Whatever the number, filter maintenance is a low cost means of reducing unnecessary energy consumption. The inset details some of the ways in which filters can be used to conserve energy. Leaking ducts can cause a 10% loss in cooling or heating air that actually reaches the conditioned space. Maintanance checks should include leak sealing programs.

It's also a good idea once a year to open up and physically inspect the insides of chillers, pumps and compressors and lubricate moving parts according to manufacturer's instruction.

If it's a well instrumented system, check the pressures, flows, and temperatures against the system design specifications. Off-normal readings are a sure sign that specific attention is required. If the gauges are accurate, an indicated malfunction tells you that you are already wasting money and inviting major failure later. Accuracy of the gauges should be checked regularly by a skilled service mechanic.

Clean-up time.

Keeping system components clear is more than just good housekeeping. It makes economic sense that dirty or corroded equipment has to work harder than clean, properly cared for

equipment.

A semi-annual tune-up is also a good time to make sure that system components are cleaned, scraped, painted and maintained in good-as-new condition.

Instrumentation and control devices come in an amazing array of shapes, types and complexities. And building control systems vary greatly in their sophistication from building to building. They all, however, have one thing in common . . . the absolute need for regular calibration to ensure efficient operation.

The control system is all there is, short of direct physical interference, to obtain energy efficiency while maintaining system operation. To reduce space temperatures or limit fan start-up to certain times, some degree of assurance is needed that controls are running your system the way it should be run.

Further, calibration should ensure that your control settings agree, either with your original design specifications, or with the settings deemed most economical at the last tune-up.

Some special areas of calibration can generate quick savings. For example, humidity control is not as important as once thought. If humidity controls haven't been touched in a few years, the system is probably running at 50 percent relative humidity. It is now generally accepted that 30 percent relative humidity is the maximum moisture level consistent with most economical energy use. The 20 percent difference can generate considerable savings.

A non-sophisticated rule of thumb for finding this efficiency level in a system without percent relative humidity control is merely to turn humidity back until getting static electricity occurs touching door knobs. Then turn it up just enough to eliminate the static electricity.

Another overlooked area of calibration is the preheat coil. Many buildings in colder climates have a preheat coil in the outdoor air intake duct, which can continually demand more cold outside air than needed when improperly controlled.

In one 100,000 sq./ft. building, a 10 degree error in preheat discharge temperature was identified as the cause of $4,000 heat waste in a single heating season.

A good point to remember in calibrating older systems is that there probably is some leeway in resetting controls to new limits, because most existing heating, ventilating and air conditioning systems are designed for "worst case" conditions. If the chiller system can keep your building cool at 120°F with 42°F chilled water, the plant can get by with higher chilled water temperatures on the 362 days a year when the outdoor temperatures are more moderate.

Temperatures should be set back.

Assuring that the system is operating efficiently is obviously critical, however perhaps the simplest and most pervasive step that can be taken is to set temperatures at the stipulated levels of 68°F in the heating season and 78°F in the cooling season. With proper dress for the season (which can account for the equivalent of 5°F in the winter and 3°F in the summer), these are reasonable, comfortable temperature settings to maintain in the plant — and they will save considerable amounts of energy and money. (With "reheat" systems the situation is somewhat more complex.)

Of course, lowering temperatures cannot be done without regard for employee relations. Without adequate communications, there will be problems of employee complaints — and even numbers of people plugging in their own electric space heaters to make up the difference; if there are some elderly or arthritic employees, special steps may have to be taken. And even with the best of communications as to the reasons for, and the results of, an energy setback, thermostat settings may have to be nudged up a degree or so.

In the vast majority of situations, however, 68°F should be adequate for the comfort of suitably dressed employees as long as drafts have been eliminated. And it will save money.

For example, in a city with an average winter temperature, setting thermostats back to 68°F in working areas will save an average 10% on fuel bills compared to a setting of, say, 72°F.

Conversely, setting the thermostats at 78°F in the cooling season will result in consumption of considerably less fuel than if the thermostat were set at a conventional 72°F — provided the higher setting is not satisfied merely by greater reheat.

But don't stop there. Nighttime and weekend temperatures should be set back even further . . . and unoccupied or seldom-used areas should

be left at as low a temperature as the contents of the building will allow.

Different building types and constructions will influence the degree of savings due to nighttime setback of temperatures — the critical factors here being the insulation value of the structure and its mass. And it is important to assure that the building can be brought back up to temperature economically.

But in most cases, there are substantial savings from three sources — heat loss savings, fan horsepower savings due to cycling, and ventilation savings due to reduction in outdoor air used during the night cycle — due to nighttime and weekend temperature setbacks.

For their part, fan horsepower savings can be substantial. If, for example, a heating system was designed to maintain an unoccupied building at 75°F during the winter, fans run continuously only when the temperature difference between the indoor and outdoor temperatures are equal to or exceed the design specifications. By setting the nighttime temperature back to 55°F in, for example, Vancouver, an estimated 18% in fan running time can be saved. In a more extreme climate such as Saskatoon, these savings climb to approximately 28 percent. Both convert to substantial dollar savings.

In considering ventilation savings due to night setback, it should be remembered that buildings using an air moving system to keep night temperature at the required value are subject to inefficiencies if the outside damper leaks when shut. And the losses can be quite dramatic. Given a 10 percent leak over a 12 hour nighttime and full weekend setback, during which fans are running full time recirculating air to maintain a minimum temperature of 60°F, the savings for each 1,000 cfm of system capacity amount to more than 14 million Btu's per year in Saskatoon, and more than 6.5 million Btu's in Vancouver. Even assuming a $2 cost per million Btu's and a system of 50,000 cfm — that's a range of from $650 to $1,400 per year that is being lost as long as the fans are running.

Reduced fan running, accomplished by a simple change to the system, would reduce these figures somewhat, but would add its own savings in fan horsepower. In fact, in most areas of Canada as much as 80 percent of nighttime and weekend fan energy can be saved.

Overall savings from night-weekend setback are essential, but depending on the size and complexity of the system, it may be difficult to fully cash in on them using a manual thermostat adjustment. Automatic controls are frequently a much better way of reducing the "human factor" and assuring that prescribed temperature settings will be adhered to.

A consultant or supplier of control equipment can help in an area like this, but one case history in this booklet will be of particular interest to plants with direct fired gas heaters controlled by local thermostats. It shows the use of a simple dual thermostat system controlled by a seven day timer which provides both temperature control and local bypasses for maximum flexibility of operation. Similar simple, inexpensive control systems can be applied to many plant and office heating and cooling systems and will, in most cases, pay handsome dividends in energy and dollar savings.

A related application of automatic controls will also reduce energy consumption. Where, for example, a time clock is being used to start boiler pumps and fans for the morning warm-up period, it stands to reason that if the building needs three hours to warm up when the outside temperature is —10°F, it may only need 20 or 30 minutes if the outside temperature is 40°F. Inexpensive warm-up controllers can be installed which measure outside air temperature and use the "U" factor of the outside wall as a constant to determine the optimal start time for heating equipment each day. It is estimated that minimum warm-up times for outside temperatures can save ½ cent per square foot for every hour of average warm-up time eliminated.

The other major area for potential dollar savings in temperature control is temperature setback for unoccupied or underutilized plant or warehouse space. Here, the rule of thumb is to set the thermostat as low as it can be set without doing damage to the contents.

As an example, at one Canadian plant, in passing from one building to another, workers had to make a lengthy walk through a large unused building which previously was kept heated by steam during the winter. Company engineers realized the energy that was being wasted heating what amounted to a huge hallway and installed timer activated infrared heaters above a pathway between the two buildings. The savings

"ENERGY CONSERVATION"

BUILDINGS
"HEATING"

BLDG. LOCATION CODE: | AREA MEASURED:

ADDRESS: | AREA:

CHECKED BY: | DATE: | TIME: | BUILDING TYPE:

TELEPHONE NO: | HEATING ON: | HEATING OFF: | OUTDOOR TEMP:

FLOORS	HALLS & STAIRWAYS 70°F (21°C)	LOCKER & LUNCHROOMS 70°F (21°C)	OFFICE AREAS & OPTING ROOMS 72°F (22°C)	EQUIPMENT SPACE ATT'D 70°F 21°C UNATT 55°F 13°C	VEHICLE AREAS 55°F (13°C)	STOREROOMS Unoccupied 40°F (4.5°C)	RATING – PERCENT		
ACT.									
POSS.									

"COOLING"

COOLING: ON: | COOLING: OFF:

	78°F (25.5°C)	78°F (25.5°C)	78°F (25.5°C)	78°F (25.5°C)				
ACT.								
POSS.								
						TOTALS		AVG. %

	DOM. HOT WATER 110°F (43°C)	CAFE. HOT WATER 180°F (82°C)	OPEN WINDOWS	OPEN DOORS			
TEMPERATURES →					LESS CONTRAVENTIONS		
CONTRAVENTIONS →							

OVER ALL PERFORMANCE PERCENT

in reduced fuel consumption to generate steam paid for the heat installation in short order.

Common sense will probably dictate the appropriate temperature for various parts of the plant, but as a guideline, the chart shows typical temperature settings used by one company for various plant facilities. Obviously, if an area needs no heat or cooling — shut if off! The more this is done, the greater the reduction in fuel bills.

Completing the last of the "four C's", a major area of consideration in reducing energy use is the use of "free cooling" wherever possible. In fact, most buildings use chilled water to cool air down to 55°F. Obviously, when the outside temperature is 55°F or less, there is no need to run chillers, pumps and compressors. Simply open the outside air dampers and use free outside air or have controls installed to perform this function automatically.

With small, self-contained refrigeration systems, it will be practical to prevent them from starting anytime free cooling is available. However, with large central plants, in most cases a decision will have to be made on a daily or weekly basis.

There are hundreds of potential areas for energy savings in HVAC systems, many of which are outlined in the case history and quick ideas section of this booklet. In many cases they required nothing more than the turn of a switch. In others, organized maintenance activities or minor modifications to system hardware are in order.

Ceiling fans — economy-sized heat recovery.

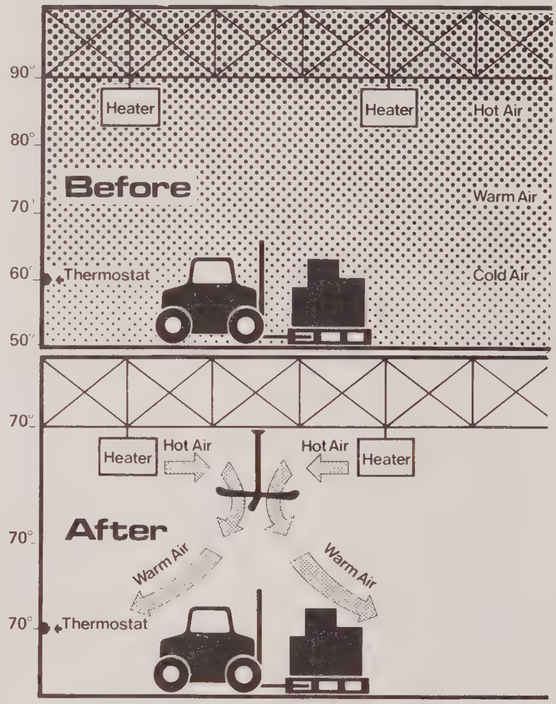
When the term "heat recovery" is used, it is generally considered to pertain to the use of heat exchange devices to recover heat from stack gases or other heated effluent. But a form of true heat recovery which can be carried out inexpensively and with virtual assurance of good results is the use of ceiling fans to reduce the heat stratification that is a feature of many industrial plants.

Hot air which rises to the ceiling of a plant and stays there in a layer or stratum is a major untapped resource of heat that in its present position does nothing to help the comfort of employees. The result is higher temperature settings and energy consumption to effectively heat the lower levels of the plant.

Installation of fans in a reasonably well insulated building can push heat back down to floor level where it serves a useful purpose often reducing the floor / ceiling differential from 20°F to 5°F — and stopping the thermostat from switching on so often. In many cases (see case histories) plant managers find the thermostat can be set 5°F or more lower than before fan installation — and at the same time get warmer temperatures at floor level.

As mentioned earlier, for each degree above 68°F the thermostat is set, fuel consumption

Reduction of Heating Costs Using Fans



increases an average of 2½ percent. Conversely, setting the thermostat back 5 degrees can often save 15 percent on a heating bill, and pay for fan installation in short order. While each individual situation has its own variables, a single "bar room" fan located at a height of about 20 feet will direct heat back over an area of approximately 2,000 sq. ft. Variable speed fans operate on as little as 167 watts of power, move 16,800 cfm of air and when controlled by a thermostat control "come on" only when needed.

A case history example in this booklet deals with

the use of a seven day timer/thermostat system which allows offshift temperatures in the plant — and fan usage — to be automatically lowered. One manufacturer claims that with the use of timers and fans, savings of 15 to 40 percent can be *guaranteed* for industrial plants where heat stratification is a factor.

This same manufacturer has developed a computerized heat loss analysis using a questionnaire approach to take into account such factors as:

- number of degree days
- building dimensions, including areas of shipping doors and other openings — together with length of time open every day
- "R" value of roofs and walls
- number and ratings of exhaust fans time schedules of plant usage
- average floor and ceiling temperature (and night set-back)
- unit costs and usage of fuel over several preceding heating seasons
- heat losses.

One additional factor in improved energy efficiency results from the ability of fans to develop "heat reservoirs" in plant material and equipment and, particularly, in a cement slab floor which during the night can help resist excessive cooling.

Among the other benefits to fan use:

- when reversed (a feature of some models) an updraft is created which can reduce roofdeck condensation during the summer months and pull warm air and fumes up and away from working areas
- when located properly in relation to overhead doors, can help establish a "continuous heat curtain" impeding the infiltration of cold air beyond the loading dock area
- can help reduce summer humidity and speed up drying and curing times
- in the food industry, can help keep insects off the product and prevent stratification from affecting food stored at higher levels of a warehouse.

Look at all heating alternatives.

As the concept of efficient energy use becomes a part of everyday industrial thinking, more and more new equipment will be developed which will be available for new and retrofit applications to help plant managers meet energy conservation objectives. Infrared heating, for example, appears to offer advantages for some industrial buildings (see case history). Infrared rays heat only the objects at which they are directed (and not the surrounding air) so heating can be directed at, say, only those areas of the plant where workers are located. Perhaps more importantly, maximum heat output is reached in just a few minutes, allowing an area to be shut down when heating is not required — or for the entire heating system to be shut down overnight where "comfort heat" is the only requirement.

Higher priced heat recovery must be considered.

Not all of the changes that can be made to heating or air conditioning systems are either simple of "inexpensive". Heat recovery systems which make use of otherwise wasted exhaust heat from various sources fall into this category. Whether or not they are economic in a given situation will depend on a number of local factors in the plant setting. But it is certain that to determine whether or not they are economic, companies must be prepared to go through a full economic evaluation which recognizes all relevant factors (see the Guidebook/Index for a discussion of means of calculating rate of return for energy conservation investments) — and not be frightened by a $10,000 or even $50,000 price tag.

The case histories in this booklet outline a number of possible heat recovery systems and further reference information on the subject is included in the "Process Design" booklet. Whether heat can be recovered directly, or whether one of a number of types of heat exchanger are required will be determined by site specific factors.

But what is crucial is that any opportunities for heat recovery be identified and assessed. Preheated exhausts of all kinds frequently offer opportunities for heat recovery. An energy audit, the case histories in this booklet, and other source material may lead you to identify

possibilities. If not, a few hours with a consultant may be well spent.

The same kind of situation applies to use of waste materials which can be burned to generate heat for plant conditioning. (The "Combustion Control" booklet in this series deals with this subject in some detail.) Again, it is not for everyone — in fact, for the present, more for large operations which generate substantial amounts of waste which can be burned cleanly. And only where there are really substantial economies of scale can the pollution control equipment be required to handle "dirtier" waste materials be justified.

Because the booklet is designed to help plant managers and others improve existing situations, no emphasis has been placed on systems such as wire mesh heating which are primarily directed, at least for the present, to new construction. A case history of retrofit wire mesh heating is discussed in the case history section, but this is the exception rather than the rule.

Similarly, "heat pumps" have not been given detailed coverage. However this is a rapidly developing area of technology and can be used for a variety of applications.
A mention of these and other new developments in energy technology is warranted, however, if only because they typify a way of thinking about energy and its efficient use which must become an "ethic" if Canadian industry is to capitalize on this area of opportunity.

Take a look at your HVAC system. How does it operate? What simple maintenance or control modifications can be made to improve its performance? What system modifications are possible that would make a major change in its productivity? Suppliers and consultants can be a great help in this regard . . . but the major impetus must come from within the plant. The savings are there for the capturing.

Further information.

As a source of further ideas and information, readers are directed to the index in Booklet 1 of this series and ASHRAE Standard 100.4P "Energy Conservation in Existing Industrial Buildings."

Guidelines to reduce energy used for distribution and HVAC systems

Heating systems.

—Clean the air side of all direct radiators, fin tube convectors and coils to enhance heat transfer.

—Keep radiators free from blockage. A one foot clearance in front of convectors, radiators, or registers is desirable. Heating systems, particularly hot water or electric baseboard radiators and low level warm air supply registers, work more efficiently if they are not blocked by furniture. Keep all books or other impediments from blocking heat or air delivery from the top of horizontal shelves or cabinets which enclose radiators, fan coils, unit ventilators or induction units.

—If radiator is set directly in front of a window where the glass extends below the top of the radiator, or in front of an uninsulated wall, insert a one inch thick fiberglass board panel, with reflective coating on the room side, directly between the radiator and the exterior wall to reduce radiation losses to the outdoors.

—Vent all hot water radiators and convectors to assure they are completely filled with water.

—Check radiator steam traps to assure that they are passing only condensate, not steam.

—Make sure that all fans, frequently inoperative in unit heaters, fan coil units, and unit ventilators, are running normally to increase the heat transfer rate from heating coils.

—Use electric or infrared units as spot heaters for remote areas, a reception desk in a large lobby, for example, rather than operating an inefficient central system for a small area in the building.

—In the public spaces of all buildings such as lobbies, corridors, stairwells, vestibules and lounges — conserve energy as follows: Where heat is provided by a unitary terminal equipment valve, turn off such equipment and remove the handles from control valves. If balancing cocks are included, turn them to the "off" position. In each stairwell of multi-level buildings, shut off all but the unit located at the bottom. Turn off heat in vestibules and foyers.

—Overhead unit heaters should direct heat to floors. Add directional louvers to focus heat to floor or area requiring heat; where possible draw return air from floor.

Single Zone Duct Systems.

—Maintain filters to reduce resistance to air flow, permitting a reduction in the time that the blower and the primary heat or cold-producing equipment run to satisfy room loads. Where possible change filters to low resistance type. A "V" type arrangement, if space permits, will provide more filter surface and less resistance, and thus requires less frequent cleaning than a straight single panel filter.

—Clean coils of lint and dirt to increase heat transfer efficiency in air handling units.

—To reduce heat loss and heat gain, repair insulation where torn, or insulate the exterior surfaces of casings where insulation is not on the interior surface. Units located outdoors on-grade or on the roof, or in non-conditioned spaces should be insulated with the equivalent of 3″ of fiberglass.

—The relationships between the supply air temperature and quantity, and the chilled or hot water temperature and quantity, and space loads cannot be oversimplified in an energy use analysis.

The further relationship between fluid temperatures and flow and the primary energy-conversion equipment can be understood only after a thorough seasonal analysis of all factors considered together. However, consider the following:

1. Lowering supply air temperatures in the winter conserves energy, reduces "parasitic" loads by reducing thermal losses from the duct and piping systems, and improves the efficiency of the system. It also reduces or eliminates wide swings in the space temperature because of overheating. However, the equipment may operate for a longer period of time and/or require a large volume of air and more horsepower, thereby cancelling some or all of the savings in energy gained by reduced thermal losses.
2. Raising supply air temperatures in the summer conserves energy by reducing heat gain in ducts and piping, and by improving the efficiency of the chillers or compressors

whenever they are in operation. Over cooling is minimized and wide temperature swings are eliminated but, again, a greater amount of supply air may be required to handle the load, necessitating more fan horsepower and/or longer periods of operation for fans, blowers, chillers, and condensers or cooling towers. In general, however, operation at the higher air temperature will prove to be cheaper.

—Where electric coils are used, operate the coils in stages, rather than all off-all on. This can be accomplished by a step controller tied to the thermostat.

—Where humidity control is not essential, consider using the chilled water coil for both heating and cooling by modifying the piping connections and removing the heating coil. The benefits are (1) the elimination of the heating coil reduces total system resistance to air flow and allows a lower fan speed to achieve the same volume through-put of supply air with less fan horsepower; and (2) when used for heating, cooling coils, which typically have a much greater surface area for heat transfer than heating coils, allow considerably lower water temperatures for a given heat output. The reduction in water temperature, in turn, minimizes heat losses from the system and allows more efficient operation of the boilers.

—Maintain the hot water and the chilled water at constant flow, but reset for part load conditions of more than 2 hours duration. Adjust the temperature to provide the desired supply air temperature (which can vary with small load changes) and reduce the heat gains and heat losses of the piping systems.

—Avoid simultaneously heating and cooling except when required for humidity control in critical areas.

—Do not operate a large system to meet the needs of a small area for humidity control or heating.

Terminal Reheat Systems.

—Shut down system completely at night, weekends, and other unoccupied periods.

—Raise the supply air temperature to allow the use of higher chilled water temperatures which in turn will increase the efficiency of the chiller.

—Reduce supply air quantity.

—Operate on demand schedule, without reheat, whenever reheat has been used for humidity control in comfort applications.

—Operate on demand schedule without reheat when zone control can be sacrificed.

—Relax humidity requirements and allow the relative humidity to drift naturally up to 65%. High relative humidity levels will reduce the need for low supply air tempertures allowing the suction temperature of the refrigerator unit to rise, decreasing energy required for refrigeration.

—Schedule supply air temperature according to the number of reheat coils in operation. If 90% of the reheat coils are working the supply air temperature is too low and should be reset to a higher level until the number of reheat coils in operation falls to about 10%.

—Ensure that simultaneous heating and cooling cannot occur by providing interlocks between the heating and cooling control systems.

Dual-Duct Systems.

—Refer to "Terminal Reheat Systems" for general recommendations applicable to dual-duct systems.

—Raise the temperature of the cold duct and lower the temperature of the warm duct.

—Under conditions where there is no cooling load, close off the cold air duct, turn off the cooling systems, and then operate as a single duct system by rescheduling the warm duct temperature according to heating loads only.

—Under conditions where there is no heating load, close off the warm air duct, shut down the heating system and, by rescheduling the supply air temperature according to cooling loads, operate the system with the cool air duct as a single duct system.

—Dual duct systems are usually designed so that either of the ducts can handle 80% of the total air circulated. Reducing the system to single duct operation, therefore, is likely to reduce the total quantity of air circulated and save a corresponding amount of energy. While the reduction may not affect space conditions adversely, it could possibly introduce noise problems requiring adjustment of dampers and/or fan speeds and acoustical treatment of the terminal boxes.

—Repair leaking dampers in mixing boxes.

—Do not bleed air into mixing box in the cooling mode in order to control dehumidification.

Multi-Zone Units.

—Set controls to reduce the hot deck temperature and increase the cold deck temperature.

—If not so equipped, provide the heating coils with an automatic control valve that will modulate to reduce the hot duct temperature according to demand. The valve is arranged so that when all hot duct dampers are partially closed, it will progressively reduce the hot duct temperature until one or more dampers are fully open.

—Provide the cooling coils with an automatic control valve that will modulate the cold duct temperature according to demand. When all of the cold deck dampers are partially closed, the valve will raise the cold duct temperature until one or more of the zone dampers is fully opened.

—Repair leaky valves and dampers.

—Shut off the fan and control valves during unoccupied periods in the cooling season.

—Shut off the cooling valve during unoccupied periods in the heating season.

Induction Systems.

—Refer to "Terminal Reheat Systems" for general measures, also applicable to induction systems.

—Reschedule the temperature of the heating water and the cooling water according to the load. If the building has a light cooling load, the chilled water temperature should be raised, if the building has a light heating load the hot water temperature should be lowered. Avoid simultaneous heating and cooling in any one zone.

—Typically, the primary supply air temperature is maintained at constant levels for cooling and heating which necessitates reheating or recooling by the individual units to meet fluctuating load conditions. The system operates essentially as a reheat or recool system with the inevitable consequence of wasted energy. To reduce this waste, schedule the temperature of the primary supply air at the air handling unit according to load; i.e. under light heating load conditions, the primary air heating coil should be modulated to reduce the supply air temperature and under light cooling load conditions, the supply air cooling coil should be similarly modulated to increase the supply air temperature. Achieve the modulation preferably by adjusting water temperatures (rather than water volumes) to the central coils. Chillers and boilers will operate closer to their peak efficiency.

—Remove lint screens in induction units and clean coils regularly.

—During unoccupied hours in the heating season, realize a major opportunity for saving fan horsepower by shutting off the primary air supply system and operating the heating coils in the induction units as convectors.

Variable Volume Systems.

—When dampers begin to close (indicating that the requirement for supply air has decreased) reduce the fan volume (and the corresponding fan power input) to the point where one or more VAV dampers are fully open again. Adjust fan volume with either inlet vortex dampers or a variable speed driver such as a multi-speed motor or SCR control.

—Reschedule the supply air temperature to the point where the damper of the variable air volume box serving the zone or room with the most extreme load is fully open. Maintaining constant supply air temperature, even when all VAV dampers are partially closed is wasteful, as it increases the duct heat losses or heat gains and precludes the advantages which accrue from hot or chilled water temperature modifications. (Before reducing fan volume and/or rescheduling supply air temperature, carry out an analysis to determine the optimal levels of adjustment for the individual building.)

—Lower the hot water temperature and raise the chilled water temperature according to thermal demands.

—Reduce total volume of air handled by system.

—Insure all VAV boxes operate in accordance with room requirements to prevent overheating or overcooling.

—Be sure, when resetting air volumes and where outdoor air is supplied by the same system, that code requirements for outdoor air are still met.

Fan Coil Systems.

—Refer to "Heating Systems" and "Single Zone Duct Systems" for general recommendations applicable to fan coil systems.

—Where a large number of fan coils are used in a building, the coils are provided with heating and / or cooling media of constant temperature, and control is achieved by varying flow rates through the coils. Consider adjusting the heating and cooling systems according to load. For example, when the heating load is light, and most of the heating control valves which vary the flow rate are partially closed, reduce the hot water temperature until one or more valves is fully open.

—In mild winter weather, and at night, shut off fans and permit the coil to operate as a convector. In severe winter weather, when the building is unoccupied but must be heated, or when excessive noise is not a problem, operate fans at high speed.

—Clean filters and coils.

—Close outside air dampers anytime infiltration equals ventilation requirements, or block off permanently.

—Block off inlets where no dampers are installed if infiltration meets ventilation requirements.

—Keep air outlets and inlets free of obstructions.

—Where fan coil units are not located in conditioned areas, insulate casings to reduce heat loss / gain.

Window And Through-The-Wall Units.

—Clean condenser and evaporator coils and intake louvers.

—Caulk openings between unit and window or wall frames.

—Remove units or cover them with plastic hood during the winter.

—Provide thermostatic control or timers to shut them off automatically.

—Turn off cooling unit and fan when leaving the space.

—Outdoor air inlets to units with resistance heaters are usually fixed, bringing in outdoor air whenever the units are operating. Close these inlets when unit is not in operation or block off entirely if infiltration meets outdoor air requirements.

Reduce Fan Power By Reducing System Resistance.

—Most duct systems are provided with balancing dampers which ensure the correct flow of air to each register or diffuser. The method of balancing which probably was used originally was to first determine the longest run, which normally had the highest resistance to air flow, and then to leave the balancing dampers in that run in a wide open position and close all other balancing dampers to achieve the required air flows. Thus, the shorter the run to any particular outlet, the more closed its balancing damper and the greater loss of power across it. Reduce resistance in the longest or index circuit so that all balancing dampers can be open, and total system resistance reduced. Further reduce resistance within all other branches or portions of the system.

—Remove unnecessary dampers or other obstructions from both supply and return air ductwork.

—Eliminate high resistance turns and elbows. One bad fitting may increase the entire system resistance by more than ½″ S.P.

—If the majority of dampers in an air system are closed or partially closed to "balance" the system, consider reducing the total air volume and opening some of the dampers to save fan horsepower.

—Clean filters, blower fan wheels and fan scroll blades frequently to reduce friction.

—Replace filters which have low efficiency and high resistance with filters offering less air resistance and greater efficiency.

—Clean the air side of all coils in air handling units. Cleaning coils also increases their efficiency so that less energy for operation of the heating or cooling primary equipment is required. (The previous steps, in themselves, increase air volume and fan horsepower. When fan speed is reduced to maintain the

same air volume fan horsepower is reduced.)

—Seal and caulk leaking joints in ductwork, air handling units, and flexible duct connectors.

—Although air leakage from the ventilating system does not increase the resistance to air flow as such, it does waste energy in two other ways:

1. It increases the total quantity of air handled by the fan over and above that required to meet the room temperature.

2. It increases the quantity of air that must be cooled or heated resulting in an expenditure of energy over and above that which otherwise would be required to meet desired room conditions.

Air leakage in the longest or most resistant duct run imposes a particularly large resistance load on the entire system since all other runs must be dampered down.

—Where direct drive fans are used and it is difficult or costly to change fan speed or motor, blank off unused portions of exhaust hoods in kitchens and cafeterias to reduce air volume and horsepower.

—Insulate ductwork where heat losses occur. Insulate ductwork used for air conditioning where it passes through non-conditioned spaces and picks up heat.

Reduce Fan Power By Reducing Air Volume.

—Reduce air volume by reducing the speed of rotation —

1) Where motor sheave is adjustable, open the "v" to reduce its effective diameter and adjust motor position or change belts to maintain proper tension.

2) Change motor sheave if no futher adjustment is possible.

3) If motors are variable speed, set controller for reduced speed.

—After implementing changes to the system to decrease the required fan horsepower, the existing motor may be too large. The efficiency of a partly loaded motor does not drop; but power factor does. For this reason power factor should be checked and corrected if required.

—If the fan is direct drive, changing the speed of rotation is expensive. However, electric motors also tend to be oversized and if the system resistance is reduced significantly, the next size smaller motor, running at a slower speed, may well be suitable. In this case, calculate the savings that will accrue due to reduced power requirements to determine whether changing motors to achieve the speed reduction is economical.

—Losses in the drive train and bearings can, if maintenance is poor, amount to as much as 20% of total power input. Examine all bearings for wear and resistance to movement. Excessive belt tension will also impose an added load on the motor. Adjust or replace slipping fan belt drives.

—Operate exhaust systems intermittently to reduce total operating time. In many buildings the toilets and other areas require full exhaust for limited periods only. With proper programming and wiring to integrate the operation of exhaust fans and dampers with light switches, an office building with a system which exhausts 100 cfm through each of 20 toilet rooms, could reduce its total exhaust to an average of only 400 cfm throughout the day.

Reduce Power For Pumps.

—Regularly adjust all pumps to control leakage at the pump packing glands. Curtail excessive waste of water by repacking, not only to conserve water and reduce losses, but also to avoid erosion necessitating costly repairs of the shaft.

—Reduce water flow where the terminal heating device can deliver heating or cooling adequately with the lower rate. For a chilled water system, take care to avoid reducing flow to the point that a lower suction temperature must be used. In general, the energy consumed at that lower suction temperature to reduce chilled water temperature (to maintain temperature or humidity control) would outweigh the energy saved by reducing the power for pumping.

—Gate valves can be used to restrict flow and save some energy, but since most hydronic systems are equipped with direct drive pumps, it is not possible to reduce the pump speed when the system friction is reduced by opening valves or removing resistances; use gate

valves to restrict flow and save some energy. It is often possible to replace the pump impeller to save motor horsepower. Refer to pump manufacturer's information for instructions.

—Check the power input to the pump motor against the nameplate rating.

Piping Systems.

—Repair torn or missing insulation on water and steam piping which pass through unconditioned spaces.

—Insulate piping, valves, fittings and heat exchangers where heat is lost to unconditioned spaces or where heat lost from the pipes adds to the summer cooling load.

—Insulate cold piping used for air conditioning where it passes through uncooled spaces and picks up heat.

—Protect pipe insulation from water and moisture to preserve its thermal resistance qualities.

—Check for high temperature differences in heating and cooling heat exchangers, which may be an indication of air binding, clogged strainers, or excessive scale.

—Repair leaks in and / or replace steam traps. Confirm the location of a leaking trap by testing the temperature of return lines with a surface pyrometer and measuring temperature drop across the suspected trap. Lack of drop indicates steam blow-through. Excessive drop indicates the trap is holding back condensate.

—Chilled water and hot water systems require near complete elimination of air: check vents before reducing water temperature to improve cooling performance or increasing water temperature to meet room heating loads.

Lighting

Lighting. Its something we all depend upon and understand. Right? Apparently not, because major amounts of energy are still wasted in industrial applications all over Canada through the use of inefficient light sources or by a lack of maintenance which ultimately increase the cost of lighting. Not that the toll stops there. How much productivity is lost, and how many industrial accidents occur because an area is underlit — either because there are insufficient fixtures, or because dirt has accumulated on lamps reducing efficiency? No one really knows, but a trip through a typical plant generally offers a clear indication that lack of knowledge or concern about lighting is very costly to Canadian industry.

Three basic questions.

In relating energy conservation to lighting in a given plant, some obvious questions need to be asked. The first of these is, Is present lighting efficient enough?. Could presently installed lighting systems be replaced with one which will result in a more efficient energy usage? An associated question is "are adequate illumination levels being provided to assure acceptable standards of safety and productivity in the plant?" The two are connected in that if additional lighting is required, in the majority of cases it will pay the company to upgrade its systems to a more efficient form of lighting.

For example, if meter measurement shows lighting levels in an incandescently-lit foundry to be 20 footcandles, what is not needed is a doubling in the number of incandescent bulbs in the system. What is required, quite frequently , is a smaller number of more efficient bulbs — providing greater lighting levels at a lower cost per lumen. This is a subject that will be dealt with in greater detail later in the text.

The next basic question examines what amounts to the opposite situation. In fact, "Could lighting levels in the plant or office be reduced?", must be asked every time. In many industrial buildings, systems were installed when energy was thought to be cheap and glaringly bright levels considered an intangible employee benefit.

Now that energy is anything but cheap, research has proven that lower light levels are often adequate for given seeing tasks and too high light levels cause physiological problems. But many plant managers are not aware of the lighting levels that exist in their plants and as a result, do nothing to remedy the problem. In many cases, one third to one half of the fluorescent lighting can be disconnected and removed without any damage to visual acuity. Where this can be done, often in conjunction with a move to "task lighting" (discussed later), major dollar savings can be attained. A case history of fluorescent lighting reduction in a later section deals with some of the physical and employee relations problems which must be handled as part of a general lighting reduction. But as a basic rule, pairs of lamps should be removed to avoid destroying ballasts. In addition, unless the ballast is completely disconnected, a poor power factor will cut into the effectiveness of the program.

If fluorescent lighting levels are only marginally too high in comparison to accepted standards, use of energy-saving fluorescent tubes should be considered. These reduce energy consumption by 15 to 20 percent with a smaller (11 percent) reduction in lighting output.

It is unlikely that incandescent systems will be providing unnecessarily high light levels, but in specific cases where a lower intensity incandescent lighting is called for, the obvious solution is a change to lamps of lower wattage.

The final basic question which must be asked is "Are lights left burning which could be turned off?". The answer is virtually every case must be a resounding "yes". And this is an area which can offer major savings if controlled properly.

Certainly old habits are not easily broken. And many employees are in the habit of leaving lights on — frequently because they "have heard somewhere" that it is more economical to leave lights on than to subject them to the wear and tear of turning them on and off.

The effect of frequent striking and extinguishing of lights varies with the type of light under consideration. And if lights are turned on and off every few minutes, it will have a significant effect on lamp life. But as a general rule — and this should be stressed with employees — it is far more energy efficient to simply turn out lights in a room where they are not required, either

because the room is not being used or because sufficient daylight is available in areas near windows.

Many things can be done to encourage employees to turn out the lights (some of these are dealt with in the "Employee Motivation" booklet in this series), but among those over which plant managers have most direct control are the provision of enough light switches in obvious places that lights can be turned out, say, in one or two offices without turning out the whole floor — and so that the well-motivated employee does not have to walk 100 feet to a central bank of switches to accomplish his objective of turning off unneeded lighting.

In conjunction with a programme to make sure employees turn off unneeded lights, it is recommended that consideration be given to seven-day timer systems that will assure that superfluous lights are not left burning through off-shift periods or over nights or weekends. Installation of these controls can often pay for itself within a short period through reduced energy consumption.

While timers and photoelectric cells have their place in internal plant and office lighting, they are a virtual necessity when it comes to curbing wasteful energy consumption caused by outdoor lighting. This is an area which calls for a two-phased programme of, first, reducing the level of outdoor lighting from "Las Vegas" levels to what is required for adequate safety and security and, secondly, installing timed or photoelectric controls to assure that, for example, display lighting is turned off at 10 p.m. or parking lot lights do not come on at the same time on the longest day of the year as they do on the shortest.

Light Levels

The term "footcandle" expresses the illumination intensity of a given area in lumens per square foot —typically the illumination of the earth exceeds 10,000 footcandles on a clear day versus 1000 footcandles on a cloudy day and 0.01 footcandles on a clear moonlit night. The task illumination levels currently being applied to 3M Company facilities.

Occupancy	**Average maintained footcandles***
Accounting	70
Conference rooms	50
Corridors	20
Design and Drafting	70
Food Service	30
Kitchens	70
Laboratories	70
Libraries	70
Lobbies	30
Locker-rooms	20
Lounge	20
Maintenance and Machine shop	50
Offices, general	70
Offices, private	50
Parking lots	0.3
Production	
Converting:	
cutting, slitting	70
service areas	40
Maker:	
unwind, wind-up	70
oven exterior	20
oven interior	50
inspection	70
Mixing, milling, chemical reactors	50
Quality control	70
Roadways	0.2
Shipping and Receiving docks	20
Stock rooms and Tool cribs	40
Warehousing:	
Rough, bulky materials	10
Finished and Semi-finished goods	20

Maintained footcandles, as opposed to initial footcandles, takes into consideration the loss of light due to lamp depreciation, dirt accumulation, etc.

Lighting efficiency has improved.

There are many industries that made substantial improvements to their lighting systems during the years when efficient light sources were in their infancy. In fact, it was not too long ago (1948-1957) that fluorescent lamps began to be installed in place of the less efficient incandescent lamps.

At that time, however, the recommended lighting levels were far less than today's illumination levels for the same task. For instance, the recommended minimum level of illumination required in a machine shop for rough bench and machine work was 20 footcandles. It is now 50 footcandles. In those days, 20 footcandles could be easily produced by incandescent lamps. However, the maximum practical amount of incandescent lighting was about 35 footcandles at lower mounting heights. At this lighting level, the heat produced by incandescent lamps — 88% of energy created — created a problem of physical discomfort that restricted its practical use in many applications.

EFFICIENCY OF LIGHT SOURCES – LIGHT AND HEAT

LIGHT SOURCE	LAMP WATTAGE	BALLAST WATTAGE	INITIAL LUMENS	RATED LAMP LIFE (HOURS)	TOTAL WATTS	HEAT GAINS (BTU/HR) (Total W. x 3.4)	LUMENS /WATT
INCANDESCENT	300 IF	–	5,720	1,000	300	1020	19
	500 IF	–	9,900	1,000	500	1700	20
	1000 IF	–	23,740	1,000	1,000	3400	24
FLUORESCENT	2 x 40 (430 MA)	17	6,300	18,000	97	330	65
	2 x 75 (430 MA)	31	12,600	12,000	181	615	70
	2 x 60 (800 MA)	20	8,600	12,000	140	476	61
	2 x 110 (800 MA)	45	18,400	12,000	268	911	69
	2 x 110 (1500 MA)	47	12,000	9,000	267	908	45
	2 x 165 (1500 MA)	55	19,800	9,000	385	1309	51
	2 x 215 (1500 MA)	50	29,000	9,000	480	1632	60
MERCURY	250	35	12,100	24,000	285	969	42
	400	50	22,500	24,000	450	1530	50
	2 x 400	75	45,000	24,000	875	2975	51
	1000	70	63,000	24,000	1070	3638	59
METAL HALIDE	175	40	14,000	7,500	215	731	65
	400	50	34,000	15,000	450	1530	76
	2 x 400	80	68,000	15,000	880	2992	77
	1000	80	100,000	10,000	1080	3672	93
HIGH PRESSURE SODIUM	250	53	25,500	15,000	303	1030	84
	400	75	50,000	20,000	475	1615	105
	2 x 400	150	100,000	20,000	950	3230	105
	1000	95	140,000	15,000	1095	3723	128

NOTE: DATA IS CURRENT AND SHOULD BE USED AS A GUIDE ONLY.

March /75

The popularity of more efficient fluorescent lamps began its major upswing in about 1958 and since that time, lamp and fixture manufacturers have developed newer, much more efficient light sources and equipment. For example, the incandescent lamp with 19 lumens per watt is now being replaced in industrial lighting applications with high pressure sodium lamps having 128 lumens per watt. In other words, one HPS lamp is doing the lighting work of six incandescent lamps.

New options available

Many of the costly outmoded lighting systems presently providing lighting for plant operation can be renovated to provide efficient lighting at a far lower operating cost.

While capital investment in a new lighting system has always been, and still is, a major consideration, in view of today's costs, the savings in operating and maintenance generally pay for the new system in a few years. And what is equally important — new systems offer better lighting and its results: less waste, better productivity, improved safety and employee morale. In short, the economics of improved lighting are very favourable, but the decision to re-light should include other "qualitative factors" if it is to be valid.

Task Lighting — light what needs to be lit.

Today's more economical lighting systems are designed to provide adequate illumination for the task performed in that area. Supplementary or "task" lighting is generally provided in the task area where higher lighting levels than the general lighting level are required.

These local task lights are located above the leading edge of the task areas, next to the operator, so that reflected light from the task surface is away from the eyes. In a machine shop with a general lighting level of 100 footcandles, a single automatic machine may require up to 500 footcandles of illumination for accurate seeing. This is most economically produced by a supplementary light.

Of course, sometimes there are areas, especially non-production areas, which do not require the same level of lighting. Here, fewer fixtures and lower wattage lamps will provide adequate illumination — and reduce costs.

Lumens per watt — a measure of efficiency.

In looking at various lighting options, an assessment of lamp characteristics reveals the important relationship between input in watts and light output in lumens. This ratio is one of a number of important criteria used in lighting systems selection.

Of the options available, incandescent lamps are the least efficient. With a rated lamp life of 1000 user hours, a 500-watt incandescent bulb produces 9070 lumens of light (19 lumens per watt). In comparison, a 1000 watt incandescent lamp produces 23,740 lumens or 24 lumens per watt.

Fluorescent lamps, with rated lamp life between 9000 and 18,000 user hours, will provide both longer lamp life and less maintenance — combined with greatly increased lamp efficiencies. For instance, the 40 watt lamp most commonly employed up to 12 foot mounting height is usually mounted in either 2 or 4 lamp fixtures. Here the lamp plus the ballast in a 2 lamp fixture require approximately 97 total watts and produce 6300 lumens of light resulting in an efficiency of 65 lumens per watt.

Gaining in usage every day are generally more efficient H.I.D. or high intensity discharge lamps. The first of these is the mercury lamp. Developed in the 1950's, and now much improved, this lamp was a major breakthrough in compact highly efficient light sources.

The rated lamp life of 24,000+ user hours represents 4-5 years of maintenance-free quality lighting. However, the lower wattage lamps represented by the 250 watt size, which are normally used in storage and other non-critical areas, have an efficiency of only 42 lumens per watt. The 1000-watt size manages to produce 59 lumens per watt and is suitable for high-bay installations.

Sharing the life expectancy benefits of other mercury lamps are reflector mercury lamps. Due to the built in reflector construction, efficiency has been reduced to 34 to 39 lumens per watt. However, with this enclosed reflector feature, they are ideal for use in foundries where maintenance is a major problem.

Re-strike, warm-up times differ.

Self ballasted mercury lamps are available to

Lamp by lamp comparison of possible savings

IF YOU ARE NOW USING:	AND CONVERT TO: Mercury	Metal Hal.	High Press. Sodium	YOU WILL GET THIS MUCH: Light(L)	Life	YOU WILL SAVE THIS MUCH IN ENERGY (W) Watts	% Watts	$ Per Year (S)
Filament Lamps (m)								
100W	50	—	—	0.8x	21x	33	66	264
	75	—	—	1.5x	21x	7	7	56
150W Par	75	—	—	1.5x	8x	57	38	456
	100	—	—	2.5x	8x	29	19	232
200W	100	—	—	1.0x	21x	79	40	632
	175	—	—	2.1x	21x	—5	—3	—40
	—	175	—	2.8x	10x	10	5	100
	—	—	150	4.2x	16x	15	8	120
300W	175	—	—	1.3x	21x	90	30	720
	250	—	—	1.9x	21x	15	5	120
	—	175	—	1.7x	10x	95	32	760
	—	—	150	2.7x	16x	115	38	920
500W	250	—	—	1.1x	16x	215	43	1720
	400	—	—	2.1x	16x	46	9	368
	—	175	—	1.0x	7.5x	295	59	2360
	—	400	—	2.9x	15x	38	8	304
	—	—	150	1.6x	12x	315	63	2520
	—	—	250	2.5x	16x	180	36	1440
750W	400	—	—	1.3x	16x	296	40	2368
	—	499	—	1.8x	15x	288	39	1804
	—	—	150	1.0x	12x	565	75	4520
	—	—	250	1.6x	15x	430	57	3440
	—	—	400	3.1x	20x	272	36	2176
1000W	400	—	—	1.0x	16x	546	55	4368
	—	400	—	1.5x	15x	538	54	4304
	—	—	250	1.3x	15x	680	68	5440
	—	—	400	2.5x	20x	522	52	4176
1500W	1000	—	—	1.6x	16x	425	28	3400
	—	400	—	0.9x	15x	1038	69	8284
	—	1000	—	2.8x	10x	420	28	3360
	—	—	400	4.0x	20x	1022	68	8176
1500W-T3 (Quartz Iodine)	1000	—	—	1.4x	8x	425	28	3400
	—	1000	—	2.3x	5x	420	28	3360
	—	—	400	1.3x	10x	1022	68	8176
	—	—	1000	3.4x	5x	350	23	2740
Fluorescent Lamps								
(4) F-40	—	—	150	1.3x	0.6x	11	6	88
(2) F-96HO	—	—	150	0.9x	1.0x	56	23	448
(2) F-96-1500Ma	—	400	—	1.0x	1.7x	13	3	104
	—	—	250	0.9x	1.7x	155	33	1240
Mercury Lamps (M)								
175W	—	175	—	1.3x	0.5x	—5	—2	—40
	—	—	150	2.1x	0.8x	20	10	160
250W	—	175	—	0.9x	0.5x	75	26	600
	—	—	150	2.4x	0.8x	100	35	800
400W	—	400	—	1.4x	0.9x	—8	—2	—64
	—	—	150	0.8x	0.8x	269	59	2152
	—	—	250	1.2x	0.9x	134	30	1072
1000W	—	1000	—	2.5x	0.6x	—85	—8	—680
	—	—	400	1.1x	0.9x	597	55	4776
Metal Halide Lamps								
175W	—	—	150	1.5x	1.6x	25	12	200
400W	—	—	250	1.0x	1.0x	142	31	1136
	—	—	400	1.7x	1.3x	—16	—4	—128
1000W	—	—	1000	1.5x	1.0x	—70	—6	—560
1500W	—	—	1000	0.8x	6.7x	460	29	3680

(m) Mean lumens based on 85% of initial lumens.

(W) Watts savings includes ballast losses

(S) Savings are based upon 100 luminaires total, 4,000 hrs per year operation, power costs $0.02/Kwh; savings = (No. of Luminaires) x (Watts per Luminaire) x (Annual hrs operation) x (Power rate in $/Kwh) ÷ 1,000 = (100) x (W) x (4,000) x (0.02) ÷ 1,000 = 8 (W).

(M) Life of mercury assumed to be 16,000 hrs and mean lumens are over 16,000 hr period.

(L) The extra light obtained is based upon average lamp lumens and does not necessarily mean that the illumination on the task will be that much more. The primary reason for this is the fact that we have not taken into account the efficiency and light distribution pattern of the luminaires.

screw into existing incandescent lamp sockets. These lamps have a short life and lower efficiency than standard mercury vapor lamps. In addition, ballasts are available to screw into incandescent sockets — the mercury lamp is then screwed into the ballast.

The metal halide lamp, one of the more recently developed H.I.D. light sources has a life somewhat lower than mercury, but its lumen efficiency is considerably higher.

For example, a 400-watt mercury lamp produces 50 lumens per watt. Metal halide produces 76 lumens per watt — a 50 percent increase in light output for the same watt input. Even more efficient, the 1000-watt metal halide lamp produces 93 lumens per watt for high bay efficient lighting.

The latest member of the high intensity discharge family is the high pressure sodium lamp. And it must be considered the most efficient light source available for commercial and industrial applications. The 250 watt size produces 84 lumens per watt while the 100 watt lamp produces 128 lumens per watt and consumes 1095 watts of power including the ballast.

All light is not "white".

Different types of lighting offer light of different colour, and colour presentation of all the various types of lamps has been improved to the extent that they are now acceptable for most applications. The one exception is the high pressure sodium lamp which because of its warm yellowish light, is not acceptable for colour matching in a fabric plant, automobile plant or any operation involving true colour recognition. (Low pressure sodium lamps, even more efficient than HPS, provide a very pronounced yellow light for exterior applications.)

Choosing and costing a system.

The selection of lighting equipment is not a simple task. In fact, for a particular application it requires a knowledge of such things as the area to be lighted, whether it is to be low or high level, open or enclosed ceiling, existence of physical obstructions such as crane ways and the dimensions of the building. It should also take into account the reflective qualities of the walls, ceiling and floor, the ease of maintenance, the presence of dust in the work area, and of course, the average footcandle level to be maintained in the task and adjacent areas. In addition, the suitability of one light source over another should be examined to provide the desired effect most economically and to obtain the maximum utilization of the electrical energy consumed.

Each light source and associated luminaire has desirable or undesirable limitations which may mean the difference between economical and wasteful approaches to the problem.

Given these factors, it may be worthwhile to examine a sample situation and determine the most suitable lighting system through a cost analysis of 6 different lighting methods. Assuming a general lighting system for:

- a machine shop of 10,000 square feet (50′ x 200′)
- mounting height 20-25 feet above the floor
- illumination of 100 footcandles (I.E.S. lighting handbook)
- plant operating requirements
  — 20 hours a day (2 shifts)
  — 5 days per week
  — 50 weeks per year = 5000 hrs
- good reflectance from ceiling, walls, and floor
- the cost of electricity is assumed to be 2.5¢ per Kwh
- lighting systems under consideration:
  (1) high pressure sodium, 400 watt
  (2) metal halide, 400 watt
  (3) mercury (deluxe) 2-400 watt
  (4) mercury (deluxe) 1000 watt
  (5) fluorescent V.H.O. — 2 — 96″ lamps (6) incandescent, 1500 watt I.F.

Given this situation and a finite number of lighting choices, the selection procedure becomes a very mechanical and not particularly complicated process. In fact, there are actually four major areas which must be considered.

- basic data
- initial cost
- operating cost
- total cost

And with these we can make a reasonable economic evaluation of the appropriate lighting system which should be installed.

The chart lists the appropriate data for each of

Lighting Cost Work Sheet

		Lighting System Description (10,000 Sq. Ft., 100 Footcandles)	High Pressure Sodium 400 Watt	Metal Halide 400 Watt	Mercury (Deluxe) 2-400 Watt	Mercury (Deluxe) 1000 Watt	Fluorescent VHO-2 Lamp 96"	Incandescent I.F. 1,500 Watt
Basic Data	1	Rated Initial Lamp Lumens Per Luminaire	50,000	34,000	45,000	63,000	29,000	34,400
	2	Rated Lamp Life (Hours) at 10 Hrs. per Start	20,000	15,000	24,000	24,000	9,000	1,000
	3	Watts Per Lamp	400	400	400	1,000	215	1,500
	4	Input Watts Per Luminaire (Including Ballast Losses)	470	460	910	1,080	480	1,500
	5	Coefficient of Utilization	.76	.76	.72	.7	.7	.7
	6	Lamp Depreciation Factor	.9	.78	.71	.66	.7	.66
	7	Dirt Depreciation Factor	.86	.87	.83	.83	.83	.83
	8	Effective Maintained Lumens per Luminaire (1. x 5. x 6. x 7.)	29,400	17,500	19,100	24,200	11,800	13,200
	9	Desired Average Footcandles on Work Surface	100	100	100	100	100	100
	10	Area Per Outlet (8. ÷ 9.)	294	175	191	242	118	132
	11	Total Luminaires For Equal Maintained Footcandles (Area ÷ 10.)	34	57	52	41	85	76
	12	Total Wattage Installed (11. x 4.)	15,980	26,220	47,320	44,280	40,800	114,000
Initial Cost	13	Net Cost Of One Luminaire	$ 222.	141.	208.	208.	80.	51.
	14	Wiring And Distribution Cost Per Luminaire @ $60./KVA	$ 28.	28.	55.	65.	29.	90.
	15	Installation Labor Cost Per Luminaire	$ 16.	16.	24.	16.	20.	16.
	16	Net Lamp Cost Per Luminaire	$ 54.	27.	25.	24.	13.	7.
	17	Total System Initial Cost (13. + 14. + 15. + 16.) x 11.	$10,900.	12,000.	16,000.	13,000.	12,100.	12,500.
	18	Annual System Owning Cost 15% of (13. + 14. + 15.) x 11.	$ 1,400.	1,600.	2,200.	1,800.	1,600.	1,800.
Operating Cost	19	Burning Hours Per Year	5,000	5,000	5,000	5,000	5,000	5,000
	20	Number of Lamps Spot Replaced Per Year – No Group Relamping (19. x 11. x No. of Lamps) ÷ 2.	9.	19.	22.	9.	94.	380
	21	Lamp Replacement Cost Per Year (20. x net cost/lamp)	$ 490.	510.	275.	220.	610.	2,700.
	22	Labor Cost For Spot Replacements (20. x Spot Labor Rate/Lamp at $4.50/Lamp)	$ 40.	86.	100.	40.	420.	1,700.
	23	Annual Energy Cost Per Year (12. x 19. x 1.3¢/KWH ÷ 100,000)	$1,000.	1,700.	3,100.	2,900.	2,700.	7,400.
	24	Total Annual Operating Cost (21. + 22. + 23.)	$1,500.	2,300.	3,500.	3,200.	3,700.	11,800.
Total	25	Total Annual Cost – Owning and Operating (18. + 24.)	$2,900.	3,900.	5,700.	5,000.	5,300.	13,600.
	26	Relative Total Annual Cost For Equal Maintained Footcandles	1.0	1.34	1.97	1.72	1.83	4.69
	27	Average Initial Footcandles (1. x 5. x 11.) ÷ Area	129.	147.	169.	181.	173.	183.
	28	Approximate Fixture Spacing (Feet) See 10.	16 x 18.5	12 x 14.5	13 x 15	15 x 16	9 x 13	11 x 12

the 28 factors in these four categories which must be considered.

The following list gives a brief description of what is meant by each term:

Basic Data.

1. *Rated Initial Lamp Lumens per Luminaire*— the exposed lamp light output without fixture.
2. *Rated Lamp Life (Hours) At 10 Hrs Per Start*— the life expectancy of various lamp types under normal conditions of voltage, temperature and vibration and when 50% of the lamps have failed.
3. *Watts Per Lamp*— the sum of the lamp and ballast wattage in each fixture.
4. *Input Watts Per Luminaire*— the sum of the lamp and ballast wattage in each fixture.
5. *Coefficient of Utilization*— this figure (always less than one) indicates the effective lumens leaving the fixture, or, the fixture efficiency. It can be obtained from the fixture manufacturer.
6. *Lamp Depreciation Factor*— the average light output of the particular lamp over its rated life— determined from the lamp lumen depreciation curve available from the lamp manufacturer.
7. *Dirt Depreciation Factor*— the lamp life to dust accumulation over a set period of time and frequency of cleaning. (The process is outlined in the I.E.S. handbook 5th edition.)
8. *Effective Maintained Lumens Per Luminaire*— determined by multiplying the initial lamp lumens by the coefficient of utilization by the lamp depreciation factor by the dirt depreciation factor, this figure indicates amount of light to be expected from the lamped fixture in service.
9. *Desired Average Footcandles On Work Surface*— the designed maintained footcandles required to provide adequate illumination for this work area. In this example, it is 100 footcandles.
10. *Area Per Outlet*— the area in square feet which one fixture must cover, it is obtained simply by dividing the effective lumens per luminaire by the desired footcandles.
11. *Total Luminaires For Equal Maintained Footcandles*— the total area to be lighted divided by the area illuminated by each fixture gives the number of fixtures.
12. *Total Wattage Installed*— the total number of luminaires multiplied by the input watts per luminaire.

Initial Cost.

13. *Net Cost Of One Luminaire*— the cost price of a suitable fixture, without the lamp (representative costs).
14. *Wiring And Distribution Cost Per Luminaire* — includes the wiring, switching, transformers, etc., required for the total installation calculated at $60/kva. It does not include the cost of luminaires.
15. *Installation Labor Cost Per Luminaire*— the estimated cost of labour to install one luminaire.
16. *Net Lamp Cost Per Luminaire*— assumes a quantity purchase for a large installation.
17. *Total System Intitial Cost*— the sum of the previous unit costs times the number of luminaires.
18. *Annual System Owning Cost*— calculated at 15% of the initial cost of the luminaires as installed, but excluding the lamp costs (costed under operating costs).

Operating Costs.

19. *Burning Hours Per Year.*
As mentioned previously, this is based on plant operating 500 hours/year.
20. *Number Of Lamp Spot Replacements Per year (No Group Relamping)*— the ratio of the burning hours to the lamp life (in hours) times the number of lamps in the system.
21. *Replacement Lamp Cost Per Year*— the number of lamps spot replaced times the net lamp cost.
22. *Labour Cost For Spot Replacement*— the number of lamps spot replaced times a labour rate of $4.50 per lamp.
23. *Annual Energy Costs Per Year*— the installed wattage times the burning hours at 2.5¢/kwh all divided by 100,000 (which puts watts into kw and cents into dollars).
24. *Total Annual Operating Cost*— the sum of costs of spot lamp replacement, labour and energy on a yearly basis.

Total Costs.

25. *Total Annual Cost-Owning and Operating*— the sum of the annual system owning cost and the total annual operating cost.
26. *Relative Total Annual Cost For Equal Maintained Footcandles*— the cost of the other 5 systems relative to the lowest cost system.
27. *Average Initial Footcandles*— the footcandle level of a new system prior to dust and aging depreciation.
28. *Approximate Fixture Spacing*— the space between fixtures to assure the resulting required footcandles, this is derived from the area per

outlet in relation to the building dimensions.

Conclusion.

From *"the total wattage installed"* high pressure sodium with 15,980 watts and 34 fixtures was closely followed by metal halide with 26,220 watts and 57 fixtures. The remaining systems are considerably less efficient in their use of energy.

When considering the "initial cost", we see what many owners usually see, that all systems are comparable in first cost.

However, *"annual cost of the electric energy"* again shows the superiority of high pressure sodium and metal halide systems *for this application.*

Total Annual Operating Cost, includes the cost of lamp replacement, reinforces the previous conclusion. And, it must be remembered that this annual cost does not include escalation.

The final line totals the owning and operating cost on an annual basis and for this example clearly shows that the best choice from these six systems would be, first, high pressure sodium and, second, metal halide. If, however, there was a requirement for accurate colour matching, metal halide would receive first consideration. It should be stressed, however, that every situation is different and in many applications fluorescent lighting, for example, may prove to be the preferable choice.

Group relamping is a much more efficient system and, obviously were it used in place of spot replacement, different numbers would be generated. (Some lamp manufacturers provide computer studies of gorup relamping intervals and associated costs).

An examination such as this is necessary if a final assessment of all relevant factors affecting lighting are to be considered for both new lighting and retrofit applications.

Maintenance — Key to Lighting Efficiency.

A well planned lighting system is designed to provide adequate visibility and comfortable seeing conditions. A well maintained lighting system continues to produce month after month, the footcandles for which it was originally designed. Anything less — including dirt accumulation, lamp burnouts and other system defects — hurts the general efficiency of the lighting installation.

In short, before adding more lights — consuming greater amounts of energy — consider what regular cleaning, maintenance and new fixtures can do for your present lighting. A new, more efficient lighting system won't stay efficient for long unless it's cleaned and maintained.

In fact, without periodic fixture cleaning and replacement of depreciated lamps, illumination levels could drop to half the installed value in a few months. In some industrial areas, dirt accumulation alone can reduce light output to 50 percent in a few weeks or even days. This means the user only gets half of the light produced from the energy he purchases. By instituting a maintenance program in such areas, the amount of useful light can often be doubled immediately. And with no capital expenditure.

To further reduce the overall cost of light with planned lighting maintenance, a system of "group relamping" should be considered an integral part of a scheduled cleaning program. If relamping and cleaning operations are done after working hours or during vacation periods, costly interruption of activities in a production area can be eliminated. In factories and offices, this can result in increased employee productivity.

Real savings in the overall cost of light accrue where lighting installations are designed for easy relamping and cleaning operations. For example, in high-pay mounting areas, there are several ways of designing for maintenance, including disconnect hangers, built-in catwalks, and maintenace carriages on trolleys. Cost of cleaning and lamp replacement can also be cut by using up-to-date techniques and modern cleaning equipment. In fact, an outside lighting maintenance company is often the most economical and reliable way of making sure lighting systems are properly maintained.

Several factors contribute to light loss, and their effect varies with the activity, type of ventilation and location of the building and lamp and fixture type installed.

Obviously areas differ as to the amount and type of dirt in the air. For example, the amount of dirt in a foundry would normally be greater than in a machine shop. And similarly, the dirt in an office near an industrial area would be greater than that in an office ina predominantly commercial

location. Also, the black dirt characteristic of steel mills is unlike the relatively light-colored variety associated with bakeries or woodworking shops.

In this regard, it's worth knowing there are three principal factors that cause light loss in every installation.

Dirt On Lamps and Fixtures.

The greatest loss of light output can usually be attributed to dirt on lamps and fixtures. It is common in a poorly maintained industrial lighting system to have light losses of 30% or more caused by dirt accumulation alone.

Typical light output depreciation, due to dirt in various areas over a period of 24 months is shown on the chart on this page. This data show the effect of dirt accumulation on the reflectors. The amount of light-loss depends on the kind and amount of dirt in the area. However, other factors which influence the rate of dirt accumulation include ventilation effect, lamp type, and fixture finish.

Ventilation Effect.

Fixture design affects the rate at which dust collects — that is, units with closed tops collect dirt much faster than those with ventilated tops. With a ventilated fixture, the temperature difference between the lamp and surrounding air creates convection currents that carry dust and dirt past the reflector and lamp.

In a study of incandescent and mercury lighting it was shown that the efficiency of the non-ventilated fixtures dropped 38% in 12 months, while ventilated ones decreased only 6% in the same period.

Lamp Type.

Dirt accumulation on a reflecting surface can be minimized if the reflector is sealed from the air, as in a dust-tight fixture or a reflector-type lamp. Here, the effect of dirt accumulation on the light output is minimized because the reflector is applied to the interior surface of the lamp. A new reflector is automatically provided when the lamp is replaced.

Reflector mercury lamps are available in a choice of beam patterns and phosphor coatings. The deluxe white lamp is a possible choice in dirty industrial areas, offering good maintenance characteristics as well as good colour rendering.

Dirt On Room Surfaces.

Good lighting practice makes use of room finishes with high reflectance values which create a pleasant environment by balancing the brightness, and efficiently utilizing the light. Naturally, collection of dirt on ceilings and walls cut reflectance value, which in turn reduces the amount of reflected light.

Lamp Lumen Depreciation.

Light output of lamps decreases as they burn. This reduction in light output is called "lumen depreciation" and is an inherent characteristic of all lamps.

Lighting Replacement — Group Or Piecemeal?

As they burn out, lamps in a lighting system can be replaced individually, or the entire lighting installation can be replaced at one time. Replacement of all lamps at a set interval, or group relamping, offers three important advantages. The sum of these advantages assures maximum light returns for dollars invested and full value for energy cost to operate.

a) *reduced cost of labour.*
Group relamping saves on labour costs because much of the travel and set-up time required to change lamps individually is eliminated. The labour cost per lamp with group relamping usually ranges from 1/5 to 1/10 the spot replacement costs.

Cost per lamp can also be reduced in a group replacement program if advantage is taken of palletized lamp shipments. Costs are reduced in purchasing, since lamps are ordered all at one time. Palletized shipments simplify handling and reduce the amount of packing material that must be thrown away, too, as compared to case lots.

b) *more light delivered.*
All lamps depreciate in light output as they are used. The earlier they are replaced, the higher the maintained illumination will be without adding to the cost of electric energy or the number of lighting fixtures. This means that people will get the visual conditions that the system was designed to provide.

c) *fewer work interruptions.*
Group relamping can be done at a convenient time, such as, during vacation shutdowns or after working hours, when there will be no interruption of operations. The number of interruptions to report burnouts or to replace them is greatly reduced.

How Group Relamping Works.

A practical method of group relamping uses lamp failures to indicate when to replace *all* the lamps in the installation. This is because the number of failures in a group reliability indicates the proportion of average life delivered by the group. For example, fluorescent lamps have reached 70% of their average life when about 10% of them have burned out. And 80% average life when about 18% have burned out. After 80% average life, the rate of lamp failure increases rapidly.

Similar lamp life studies can be made of high intensity discharge light sources from available mortality curves. An alternative is to consult a lamp manufacturer. Some have computer programs available which provide this information from plant input data.

Three Basic Group-Relamping Systems.

The "mortality curve" method of determining the group replacement interval can be used in three basic systems:

1. Group relamping with no interim replacements.
2. Group relamping with interim replacements, using used lamps.
3. Group relamping with interim replacements, using new lamps.

System 1.

Individual burn-outs are ignored until the number of burn-outs indicates that the group relamping point has been reached. For example, when 10 lamps in a 100 lamp installation have burned out, 70% of the life has been reached, and all the lamps should be replaced.

This system is simple and quite suitable to large areas where each location receives light from several fluorescent lamps, and where appearance of the lighting system is not a major factor. Its chief advantage is that the only labor cost is that of group relamping — no individual lamp replacements are made during the interim. Generally speaking, it is recommended this system should *not* be used with instant or pre-heat start ballast since failed lamps remaining in the socket for an extended period of time will cause overheating of the ballasts and will significantly reduce ballast life.

System 1 is limited to fluorescent relamping intervals of not more than 70% average life because of the reduced illumination. And is not suitable for point source lighting systems as the light distribution is seriously affected by individual burn-outs.

System 2.

Here, when the installation is group relamped at 80% average life, 20% of the best remaining fluorescent lamps are set aside to use as replacements before the next group relamping. These should be the brightest lamps with the cleanest ends, and as lamps burn out, they are replaced from this stock of interim replacement lamps. When this stock is exhausted, it is the signal that the next group relamping is due. Convenient timing of group relamping is also an important factor. For fluorescent and H.I.D. lamps, the interval is as follows:

- industrial plants and office buildings on single shift operation have about 2500 to 3000 burning hours per year. In this case, group relamping every 3 or 4 years is convenient and economical for fluorescent lamps. For mercury lamps, the relamping interval is 5 to 6 years.
- factories on double shift operation lamps 4000 to 4500 hours per year. Scheduling group relamping every 2 or 3 years is practical for fluorescent. Mercury relamping is a 3 to 4 year intervals for for three shift operation, plan on about 6500 to 7500 hours of use per year. In this instance, relamping every 2 years is called for. With mercury, however, about 3 years would be the interval. With this system, lamp replacement between group relamping has the advantage of keeping all fixtures lighted, but may be more expensive than system No. 1.

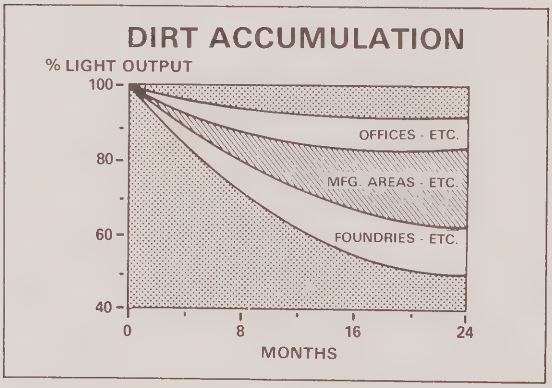
System 3.

This more recently advocated method has been widely accepted by industry due to the

increasing costs of labour and replacement parts (lamps and ballasts). Using new lamps for interim replacements assures minimum wear on the ballast and maintained illumination for efficient operation until the scheduled group relamping period has been reached. As a system, it is recommended for management consideration because it protects the ballast — the most expensive component in the fixture.

Cleaning Lights — Seeing Is Believing.

A lighting system which is cleaned at regular intervals offers the user many benefits. Dust and dirt absorb much of the light produced by lamps. Even in relatively clean working environments, lighting levels can be increased by more than 50 percent simply by cleaning the lamps and fixtures. The accumulation of dust on ceilings and walls reduce the effective light reflectance of these surfaces. And as mentioned earlier, scheduled cleaning or repainting with high reflecting colors will appreciably contribute to lighting system efficiency.



Not surprisingly, clean lighting fixtures and reflecting surfaces improve the general appearance of work areas and promote good housekeeping practices. Employees respond to clean surroundings and are frequently more productive.

Cleaning Intervals.

The cleaning interval selected for a lighting system depends primarily on how clean (or how dirty) the area normally is. For instance, once a year may be often enough to clean fixtures in an air conditioned office. But for areas such as general assembly and machine shops, twice-a-year cleaning is normally required. In locations such as foundries, where the most severe dirt conditions prevail, cleaning intervals of once a month may be needed to maintain reasonable lighting efficiency.

The time and labour involved in cleaning lighting systems have increased greatly in the last few years because lighting systems have become more complex. For the same lighting level, for example, fluorescent installations have more area per fixture as well as more fixtures to clean than mercury, metal halide or high pressure sodium systems.

Cleaning a fixture usually involves all of the following steps:

- remove and clean louvers or plastic diffuser
- remove lamps and clean
- install socket covers and shock protection (fluorescent)
- clean top and outside of fixture
- clean inside of fixture
- remove socket covers (to free for relamping)
- replace lamps
- replace louvers or plastic diffuser

The order in which the cleaning steps are taken will vary somewhat with the type of fixture, mounting height, and maintenance equipment.

It should be stressed that fluorescent lamps should be allowed to "drip dry". Wiping can compact a static charge to the lamp which could interfere with starting-up.

CASE HISTORIES

Air curtain allows preheating of make-up air

The situation: In a 250,000 sq. ft. plant in Montreal producing railway car wheels, in-plant environmental control requires that more than 500,000 cfm be exhausted from the building. This created a large negative pressure which in turn caused a large inrush of cold air during the winter through openings such as shipping doors. Because of the adverse effect on working conditions, both unions and government had applied pressure on management for corrective measures.

Action taken: The company implemented a system to introduce a minimum of 500,000 cfm of fresh air make-up to the plant and to use clean process heat to preheat the make-up air. Using a patented "controlled air flow" technique, at least 40,000 Btu/hr from the heat treat furnace area was utilized to temper the incoming air. No duct work, heat exchangers or elaborate recuperation was required. The equipment package included only supply air fans and directional air movers (tangential air curtains) to accomplish the objective.

Energy savings: A minimum of 40,000 Btu/hr would have been required from an external heat source to heat the 500 Mcfm incoming air.

Dollar savings: Based on an 8,000 degree day heat load in the Montreal area and a 24 hr/day, 5 day/week operation, this represents an estimated saving of approximately $150,000/year.

Cost of improvement: $150,000.

Recommendation: Consider all forms of waste heat capitalization before opting for one system. The designer of the system above states that under the right circumstances, cost can be as much as 75% less than a typical heated, fresh air system.

Ceiling fans reduce heat stratification

The situation: Leigh Metal Products Limited, London, Ontario heats its 75,000 sq. ft. plant with 15 direct fired gas heaters just below roof level. Until recently thermostats on the heaters were set at 85°F in order to achieve an ambient temperature of 70°F at floor level in the plant. The company realized through measurement that large amounts of heat were collecting under the roof of the plant producing at 15°F differential between floor and ceiling temperatures.

Action taken: The company installed a large blade circulating fan on an experimental basis and measured the effect on heat stratification. Results showed greatly improved heat distribution with the differential between ceiling and floor reduced to 2°F. As a result, a further nine fans were installed in various areas of the plant—activated by seven day timers to coincide with working hours. The timers also control burner thermostats allowing lower temperature settings during nights and weekends.

Energy savings: Preliminary results indicate initial estimates of a 10 percent saving in gas consumption are conservative.

Dollar savings: 10% of $20,000 (1976 gas bill) = $2,000/year.

Cost of improvement: $3,410.

Recommendation: Look to recirculating fans to reduce heat stratification in the plant and to reduce heating bills. Leigh's experience indicates that some complaints will be received from employees if the fans are located directly over working areas; however, employees requested that fans be left on in the summer for the cooling effect created by better air circulation.

Closed exhausters keep heat in

The situation: At the 125,000 sq. ft. Cambridge, Ontario plant of Electrohome's Industrial Products division, an energy conservation committee was still in its infancy. Its co-ordinator, however, decided on a number of "quick fix" energy conservation measures which could be carried out quickly, at no cost in areas of high energy use. Among the first of these considered was the possibility of closing for the winter some of the roof exhausts used to provide insulation and vent fumes created by various processes.

Action taken: While exhausts over the soldering

and die casting areas were left open, 14 of the exhausts were shut—by simply closing the damper. Turnover of air in the plant was provided by two other sources—40 overhead fans along with other fans in spray booths.

Computer saves energy on several fronts

The situation: At the Sheraton Centre Hotel in Toronto, a management audit of power bills indicated a potential for substantial savings through better control. Specific concerns were reduction in peak electrical demand, maintaining higher temperatures in mixed air sections of air handling units; and gaining more effective control of booster coil systems and more efficient control of booster systems.

Action taken: A custom designed computerized energy automation centre was installed in the hotel to reduce electricity, steam and water consumption. The computer is programmed according to occupancy so that when occupancy is down or when individual meeting rooms are not in use, lighting and heating are shut off or lowered. It is also programmed to indicate breakdowns in the systems and to signal when a specific piece of equipment requires overhauling. A member of the engineering department underwent extensive training in the use of the system.

Energy/dollar savings: 20% of consumption = $110,000/year.

Cost of improvement: $200,000 including some necessary overhauling of equipment and rewiring.

Recommendation: Computerized controls for many industrial applications may be the energy conservation save of the future, keep an eye on technological developments in this area.

Dual thermostat controls control offshift temperatures

The situation: At a number of Westinghouse Canada Limited plants, heated by direct fired gas burners, management have recognized the savings available from automatic setback of night and weekend plant temperatures—rather than relying on a system of manual thermostat controls at each heat source.

Action taken: A time circuit is wired up in which a seven-day central timer activates a "night thermostat" (preset at 60°F) each evening from 4:00 p.m. until 7 a.m. and on weekends. A manual override does exist at the burner to allow janitorial staff or someone "working late" to leave the thermostat controlling the burner and fan on the "day" setting. While there is generally a thermostat at floor level to display temperatures, it can not be used by an employee to control the function of the gas burner.

Energy/Dollar savings: Depends on local circumstances.

Cost of improvement: Minimal.

Recommendation: Automatic, timed controls for lighting and heating systems remove much of the "human factor" from the control of energy conservation and can be counted on to "pay for themselves" in short order.

Electrostatic precipitators keep the heat in

The situation: At International Harvester's Candiac, P.Q. plant four 5,000 cfm roof mounted fans had been used to exhaust contaminated air from the welding department 91,640 square foot plant. The company realized that considerable heat was being lost to the atmosphere.

Action taken: The company installed 12 electrostatic precipitators (880-watt, 2500 cfm) to clean and filter air internally and virtually eliminate exhausted to the environment.

Energy savings: Given a 5-year outside temperature (Set to April) of approximately 30°F and an average inside plant temperature of 68°F and 2560 hours of operation over the heating season:
4 fans × 5,000 cfm × .018 (Specific heat of air) × (68° - 30°F) × 60 min. × 2560 hrs = 2.10 MMMBtu/year.

Dollar savings: 2.10 MMMBtu = 2.10 MMcf @ $2.00/Mcf = $4,200/year.
Operating cost of exhaust fans = $452/year.
Operating cost of precipitators = $677.
Net savings = $4,200 − (452 - 677) = $3,975/year.

Cost of improvement: $25,000.

Recommendation: Consider the use of electrostatic precipitators to enable plant air to

be recirculated — reducing heat loss to the environment. An improvement of operating environment is a result of a precipitator system which should somehow be factored into the decision making process governing allocation of funds for a conversion.

Enthalpy controls on air conditioners

The situation: At Dominion Textile in Sherbrooke, Quebec, in a typical open washer system, air returned from a manufacturing space at 80°F and 32% relative humidity is cooled and dehumidified. The energy removed from the air is h, the difference in enthalpy between the two conditions. Outside air is frequently cooler than the return air.

Action taken: Using the principle of enthalpy control, automatic dampers were installed to exhaust room air and bring in outside air when the outside air was cooler.

Energy savings: With refrigeration operating from April 15 - October 15, 5 days/week, and with 2 weeks of downtime;

$$24\,\frac{\text{weeks}}{\text{year}} \times 5\,\frac{\text{days}}{\text{week}} \times 24\,\frac{\text{hrs}}{\text{day}} = 2{,}900\ \text{hrs/yr}$$

without controls:

Btu per 100,000 cfm air $= 4.5 \times 10^5 \times$ H $\times$ hrs

Kwh per 100,000 cfm air $= \dfrac{4.5 \times 10^5}{12{,}000} \times$ h $\times .9$

$= 33.8 \times$ h $\times$ hours.

Kwh $= 33.8 \times (27.1 - 19.1^*) \times 2{,}900 = 790{,}000$ Kwh/yr

with controls:

calculated to be 320,000 Kwh/yr = 320,000 Kwh/yr

energy saved = 470,000 Kwh/yr.

Dollar savings:

470,000 Kwh @ \$.008 = \$3,760 per year.

470,000 Kwh @ \$.025 = \$11,750 per year.

Cost of controls: \$4,000.

Recommendation: Explore the use of enthalpy controls to reduce refrigeration loads.

*from weather data for Sherbrooke, Quebec.

Expansion wall insulated

The situation: At the Canadair plant in Montreal, a large wall 200 feet long by 60 feet high, with a northwest exposure, had never been insulated. Built of corrugated asbestos siding, it had been constructed with a possible future expansion in mind that would have caused the wall to disappear or become an interior partition. During the heating season, three large unit heaters were burning constantly without reducing the substantial level of employee complaints about drafts and cold in the adjacent working area.

Action taken: Having considered other types of insulation, the company's energy conservation co-ordinator decided upon a spray application of 2-inch mineral fibre with an R factor of .13 and excellent fireproofing properties. The material, which offered the greatest insulation value per dollar for this application, was applied without disrupting work during a 15-day period during the plant's annual two week summer shutdown.

Energy savings: Projected savings are the equivalent of 36,000 gallons of oil during the first heating season.

Dollar saving: 36,000 gal @ \$.35/gal = \$12,600/year.

Cost of improvement: \$22,000.

Recommendation: Consider insulating any exterior plant wall not yet adequately protected against heat loss. Insulation projects are an obvious change for which it is generally relatively easy to obtain management approval — and to establish a "track record" for future, more esoteric, programs. Bear in mind that approval of the firm which holds your company's fire insurance will be an important input into the decision of which of the many insulating materials on the market to choose.

Fixture removal cuts fluorescent lighting costs

The situation: A lighting survey at National Defense Headquarters in Ottawa determined that 800,000 sq. ft. of usable office space was overlit to general levels of 120 footcandles using fluorescent fixtures. Based on government guidelines, a decision was made to reduce lighting levels to 75 footcandles — accomplished be removing 255 of fluorescent tubes.

Action taken: After an evaluation of the continuous strips of double 40-watt tubes a 42-inch pitch, the most aesthetically pleasing pattern was chosen and appropriate tubes removed from a complete half floor of the building. After a month's experience with the lighting change, a questionnaire was sent to all occupants of the area asking for comments. Since feedback was positive and many people

found the lighting levels less stressful and less conducive to eye strain, it was decided to modify the whole building. A letter was then written to all occupants advising why the step was being taken (conservation), the prevailing lighting levels, the revised lighting levels and the saving that would result in energy and dollars. The work was carried out over nine weeks by two casual labourers hired for the job. The pattern for light removal was strictly adhered to unless the lighting level on a task fell below 70 footcandles. Few deviations were required. Light levels in drawing offices were left untouched and removed bulbs were stored for future use as replacement.

Energy savings: Not yet measured; but estimated to be approximately 5 MM Kwh/yr reduced by a 19.5% increased heating requirement due to loss of heat from the lights (itself offset by a 27.8% reduced cooling load in the summer).

Dollar savings: Calculated at a net value of $80,000/year.

Cost of improvement: $5,555.

Recommendation: Look at the possibility of reduced lighting levels in plant office areas. Careful consideration should be given to whether or not to remove the entire fixture or just the tubes. National Defence decided that the ballast consumption was so low and the cost of removal so high (est. $75-100,000) as to make removal unwarranted. However, ballast current is an inductive load and if large enough can have an effect on plant power factor. Certainly, it is well worth the effort to keep employees informed and involved in any change so fundamental as lighting levels in the office. In this regard, the best situation from an employee relations standpoint is generally the removal of fixtures and replacement of the lens with ceiling tile.

Fluorescent fixtures replace incandescent bulbs

The situation: The Toronto plant of Sangamo Limited was more than half lit with energy inefficient incandescent bulbs. Aside from the problem of insufficient lighting levels (36 footcandles overall) in many areas of the plant, the company realized from its own knowledge and from a detailed survey carried out by a lighting fixture manufacturer that a more efficient lighting source would produce substantial energy and labour savings. A 12 foot ceiling eliminated possible use of high pressure sodium fixtures.

Action taken: 293 300-watt and 74 200-watt incandescent bulbs were replaced with 146 8-foot, 180-watt fixtures and 109 96-watt 4-foot fixtures. The project was carried out as a "fill-in" job for plant electricians.

Energy/dollar savings: Even with 45% greater overall lighting levels, use of more efficient fixtures saved $6,500 in the first year of operation. Lighting maintenance was also reduced considerably.

Cost of improvement: $12,500

Recommendation: Look to lighting modifications as one of the first steps to energy conservation in your plant. Lighting changes offer highly predictable results and are a visible sign of progress to all, including those responsible for approving capital programs. One major spinoff benefit from improved illumination in the case of Sangamo was better quality control on the plating line. The company is now considering "group re-lamping" to reduce maintenance costs even further—replacing every lamp in the plant on two year intervals.

High pressure sodium lighting more efficient than fluorescent

The situation: Canadian General Electric were lighting 15 work bays in one of their high-roofed Toronto Industrial buildings using 84 two-lamp fluorescent fixtures. The 168 215-watt fluorescent lamps produced an unsatisfactory light level on the plant floor of approximately 30 foot candles and, at the same time, consumed excessive amounts of energy due to the efficiency of the light source.

Action taken: Fluorescent fixtures were removed and replaced with 28, 400-watt high pressure sodium fixtures, resulting in an improved lighting level in excess of 50 foot candles.

Energy saved: Previous consumption — 39.5 Kw × 8 hrs./day × 5 days/wk × 50 wks/yr = 79,000 Kwh/yr.
Present consumption — 13.3 Kw × 8 hrs./day × 5 days/wk × 50 wks/yr = 26,600 Kwh/yr.

Energy saving = 52,300 Kwh/yr.

Dollars saved: Reduced consumption @

$.025 per Kwh	= 1310.00 per year.
Reduced demand charges	$1370.00 per year.
Total	$2680.00 per year.

Cost of improvements: $7,500 (see below)

Recommendation: Investigate the use of more energy-efficient lighting sources for your plant or office. Based on a simplistic analysis, the "payback period" for the above energy conservation investment would have been greater than 2 years and, therefore, potentially "unattractive" to some companies. Under any circumstances, a DCF rate of return analysis is a more complete measure of the worth of a given investment. In the case of lighting improvements, to be valid the analysis should take into account not only energy savings but also the increased lighting levels and consequences such as increased employee productivity.

Hot water heating via air conditioning cycle in a restaurant

The situation: Large users of hot water should be able to recapture heat from building air conditioning systems. A restaurant, operating 24 hrs/day, and associated with a food processing facility, was used to test the concept.

Action taken: A 15-ton compressor was selected as the heat source. A tube-in-tube heat exchanger was chosen to transfer the heat of compression from the hot refrigerant gas to the water. The hot gas was circulated through the outer tubes and the water through the inner tubes of the exchager. The water side of the exchanger was connected by a piping loop to a 176-gallon preheat tank. Water was pump-circulated through the loop. This preheat tank was connected to the electric water heat inlet. The appropriate pump circulated water between the heater and the storage tank . . . this maintained the same temperature in both storage tank and heater. Simultaneously, the other pump circulated water between the heat exchanger and the preheat tank to maintain high temperature in the preheat tank. When hot water was drawn from the storage tank for use, hot water from the water heater refilled the tank. Cold water from the city main replaced the hot water after it left the hot water system.

Energy savings: In a restaurant where the air conditioning season is about eight months long, calculations showed that 49% of the heat required for hot water for the year was supplied by the waste heat recovery system. This amounted to 61,900 Kwh.

Dollar savings: At $.025/Kwh, (61,900) ($.025) = $1,547/year.

Cost of improvement: Capital costs, labour, and installation amounted to $2,370. (1962).

Recommendation: Virtually any facility using quantities of hot water can benefit by recapture of waste heat from air conditonining units.

Incandescent/hps combination increases illumination

The situation: The forge complex within the Hamilton plant of International Harvester Limited was inadequately lit to an average of 5-10 footcandles with the following combination of incandescent, fluorescent and mercury vapour lighting:

Before		**Load**
(120)	300 W incandescent	= 36.00 Kw
(40)	500 W incandescent	= 20.00 Kw
(25)	94 W 2 tube 4′ fluorescent	= 2.35 Kw
(92)	174 W 2 tube 8′ fluorescent	= 16.01 Kw
(25)	460 W mercury vapour	= 11.50 Kw
Total		85.86 Kw

Lamp wattage ratings include ballasts.

Action taken: The company installed the following combination of fluorscent and high pressure sodium fixtures:

New		**Load**
(88)	470 W high pressure sodium	= 41.36 Kw
(40)	174 W 2 tube 8′ fluorescent	= 6.96 Kw
Total		48.32 Kw

Lamp wattage ratings include ballasts.

The combination of HPS and fluorescent lowered power consumption, provided and increased illumination by 300% to an average 15-40 footcandles. Fluorescent tubes were used to provide lower wattage "task lighting" and in some cases to provide some lighting in the event

of a return to service after a power failure. Start up time on HPS approaches 10 minutes.

Energy savings: Reduction in Kw consumption = 85.86 − 48.32 = 37.54 Kw. Usage = 267 days × 24 hr = 6400 hrs/yr.

Dollar savings: Demand component — (37.54 Kw) ($3.60 kw/mo.) (12 mos.) = $1621.73/yr.

Consumption component —
(37.54 Kw) ($.0105/Kwh) (64000 hr./yr.) = $2522.69/yr.

Total Savings = $4144.42/year

Cost of improvement: $38,000 including removal of existing fixtures, rewiring panels; new panels; lamps; fixtures and all labour.

Recommendation: Look to high pressure sodium lighting — in conjunction with fluorescent fixtures for "task lighting" to both increase illumination and reduce power consumption. Where fluorescent, incandescent or some other form of lighting is required to protect against 10-minute blackouts after a power failure, consider using a relay that shuts off these lights once the high pressure sodium lighting has started up. These relays are inexpensive and easily available, and will provide real dollar savings.

Light coloured paint on ceiling improves illumination

The situation: Leigh Metal Products in London, Ontario was concerned about rust on the inside of its 20-year old corrugated metal roof and decided to paint it with rust retardant as an interim step before considering roof replacement. They were also aware that fluorescent lighting levels in the plant could be brighter.

Action taken: Plant engineers decided to paint the 80,000 sq. ft. roof with a light coloured paint to give better lighting reflectance.

Energy savings: None directly. However, measurements showed a 10 percent gain in plant light levels.

Dollar savings: Installation of lighting fixtures to achieve greater illumination would have incurred a substantial cost.

Cost of improvement: None.

Recommendation: Explore the use of light coloured paints for floors, walls and ceilings. Regular cleaning of bulbs, tubes and fixtures will also markedly improve lighting efficiency.

Lower thermostat setting reduces heating load

The situation: In a U.S. plant manufacturing slip covers, on one eight-hour shift, five days per week, management recognized an opportunity to save energy dollars by maintaining temperatures at 68°F during working hours and reducing temperatures to the lowest allowable level during non-working hours. The plant consists of a 4,800 sq. ft. office building attached to a 100,000 sq. ft. production building. Both are electrically heated.

Action taken: Thermostat settings were placed at 68°F during working hours — requiring some supplemental heating from lighting in extreme winter weather (average outside temperature 53°F during the heating season). Space temperatures were kept at 58°F during all off-hours. This also required use of lighting to supplement heating:

Energy/Dollar savings: 4,175 MMBtu/yr and $10,437/yr @ $.025/Kwh (purchase power) as per the following calculations.

Total hours = 258 days/yr × 24 hrs/day = 6,192 hrs/yr.

Non-working hours = 258 days/yr × 1 wk/7 days × (168 − 40 hr/wk) + 4 holidays × 24 hrs/day = 4,813 hrs/yr.

Working hours = 6,192 hrs/yr − 4,813 hrs/yr = 1,379 hrs/yr.

Energy required to maintain 68°F for the total heating season;
Annual heating energy = 533,590 Btu/hr × 6,192 hrs/yr = 3,300 MMBtu/yr.

Energy required by the reduced heating schedule;
During working hours = 533,590 Btu/hr × 1,379 hrs/yr = 736 MMBtu/yr.

Non-working hours = (58-52)F/(68-52)F × 533,490 Btu/hr × 4,813 hrs/yr = 963 MMBtu/yr.

Total energy required = 736 MMBtu/yr + 963 MMBtu/yr = 1,700 MMBtu/yr.

Heat saved per season = (3,300 − 1,700) MMBtu/yr = 1,600 MMBtu/yr.

Electricity saved = 1,600 MMBtu/yr × 1 Kwh/3,412 Btu = 469,000 Kwh/yr.

Extra lighting required = 686 hrs/yr × 75 Kw = 51,500 Kwh/yr.

Net electrical savings = (469,000 − 51,500) Kwh/yr = 417,500 Kwh/yr.

If the utility uses 10,000 Btu fuel/Kwh;
Annual energy savings = 417,500 Kwh/yr × 10,000 Btu/Kwh = 4,175 MMBtu per year.

Annual cost savings = 417,500 Kwh/yr × $.025 Kwh = $10,437/year (purchase power).

Cost of improvement: Nil.

Recommendation: Maintain temperatures at 68°F in the daytime and at the lowest practical temperature during non-working hours.

Major fan installation cuts consumption, heat loss

The situation: Management at the Candiac, P.Q. plant of International Harvester Ltd. realized that heat stratification existed in the plant and that if a down draft could be initiated, warm ceiling air would be forced to the floor — improving the plant temperature gradient (78°F ceiling, 68°F floor) and reducing both the heating load and energy consumption. Plant heating is by gas fired unit heaters — with a load of 9.82 MMBtu/yr.

Action taken: 47 56-inch diameter variable speed (0.280 rpm) fans with 85 watts consumption at full speed and delivering 18,500 cfm were installed around the 91,640 square foot plant. Ceiling temperatures at the original thermostat setting were lowered 5°F — permitting the thermostat to be lowered 5°F when the fans are in use.

Energy savings: According to the ASHRAE handbook, a 3% reduction in fuel consumption is achieved for each F° thermostat settings are reduced.
Savings = 5°F × 3%/F° × 9.82 MMMBtu/yr = 1.5 MMMBtu/yr.

Dollar savings: 1.5 MMMBtu/yr = 1.5 MMcf/yr @ $2.00/Mcf = $3,000.
Operating cost for fans = 46 × .085 Kw × .025 Kwh × 3840 hrs. = $375/yr.
Net savings = 3,000 − 375 = $2,625/year.

Cost of Improvement: $14,500.

Recommendation: Consider the use of ceiling mounted fans to eliminate temperature gradient and reduce energy consumption. One bonus to bear in mind — with lower ceiling temperatures, heat losses through roof exhausters and the roof itself are reduced.

Metal halide lighting replaces incandescent

The situation: The Winnipeg galvanizing and bolt shop of Manitoba Bridge and Engineering, a 19-ft. high, 320-ft. by 56-ft. plant, was originally lighted by 48 500-watt incandescent lamps. The prime objective in relighting the plant was to achieve greater light levels without increasing energy costs and without incurring costs for additional wiring.

Action taken: using a more efficient metal halide light source, a contractor replaced on a one-for-one basis, each of the 500-watt incandescent lamps with a metal halide fixture consuming about 460 watts of electrical energy. Illumination was improved by approximately 300% — raising light levels in the plant from an average of 15 footcandles to 50 footcandles.

Energy savings: Minimal; however, substantial gains in lighting levels were attained and energy consumption decreased by approximately 2 kw.

Dollar savings: Assuming 80 hr/wk, 48 wk/yr operation; 80 × 48 × 2 = 7,680 Kwh @ 2.5¢/Kwh = $192/year.

Cost of improvement: Not available.

Recommendation: Consider more efficient lighting sources to improve or maintain existing light levels while reducing consumption of electrical energy. Where installation of new fixtures can not be economically justified, consider more efficient bulbs that will use the previous fixtures.

Oven exhaust heat used for space heating

The situation: A survey of a drying oven in a U.S. plant showed that a significant amount of heat was being lost in the 10,000 cfm of air being exhausted at a temperature of 300°F. A prime

use for this heat was determined to be space heating in the plant.

Action taken: Management decided upon a heat wheel for recovery of the oven exhaust heat and chose a heat wheel with a design heat recovery efficiency of 78 percent. Outside ambient air temperature averaged 39°F.

Energy/Dollar savings:
Heat recovered = 10,000 cfm × 0.0763 lb/cf × .24 Btu/lb °F × 0.78 × (300 − 39) °F × 60 min/hr. = 2.24 MMBtu/hr.

If a natural gas heater with a fuel efficiency of 70% were used to provide this amount of heat for the average 6588 degree days per year.
Annual fuel required = 2.24 MMBtu/hr × 8 Hr/day × 6588 × 1/(65 − 39) °F × 1/0.70 = 6490 MMBtu/yr.

If the fuel cost is $2.00/MMBtu.
Annual saving = 6490 MMBtu/yr. = $12,980/year.

Using a heat wheel eliminates the fuel cost, but requires power to operate a fan.

If 4 hp is required for the fan, at $.025/Kwh.
Fan power = 4 hp × 0.746 Kw/hp × 8 hr/day × 6588°F day/yr × 1/(65-39) × $.025 Kwh. = $151./year.

Annual cost savings = $12,980 − $151/yr = $12,829/yr.

Cost of improvement: Estimated $10,000 (in 1977).

Recommendation: Investigate the feasibility of recovering heat from hot exhaust streams for space heating and othe applications. These systems can often eliminate the need for space heater units — or be used to preheat oven entering air.

Radiant heaters replace steam system

The situation: The Scarborough, Ontario plant of Canadian General Electric was heated with a steam system utilizing Bunker "C" oil as fuel. The 70,000 square-foot 2-storey office area was heated with radiators; the 240,000 manufacturing area (25 to 75 foot ceilings) with forced air steam units. Plant management realized that steam was no longer an important factor in plant processes (needed for about one week per year) and that both economics of the steam system and heat distribution achieved throughout the plant were unacceptable. Five stationary engineers were required to maintain the system.

Action taken: Office heating was converted to gas-fired hot water heat and plant heating changed to ceiling mounted high intensity infra-red gas heaters. One boiler and one stationary engineer were maintained as part of the new system.

Energy savings: Bunker "C" consumption: 456,000 gal @ 180,000 Btu/gal. = 82 MMM Btu/yr.
Natural gas consumption: 40,000 Mcf @ 1,000 Btu/Mcf. = 40 MMM Btu/yr.
Savings: = 42 MMM Btu/yr.

Dollar savings: 42 MMM Btu/yr @ $2.00/Mcf = $84,000/yr.
Additional savings were generated through reduced electrical consumption on forced air units (250,000 Kwh/yr); water consumption (1 MM gal/yr); and on staff reductions.

Cost of improvement: $300,000. This represented a 1½ year payback at the time of conversion.

Recommedations: Don't overlook radiant heating as a possible alternative to existing outdated heating systems.

Reduced ventilation conserves fan energy

The situation: A new 150,000 sq. ft. warehouse was constructed with provision for five air changes per hour — requiring a 10 hp motor (with a fan load of 9.83 hp) driving a 24 inch centrifugal fan at 915 rpm to deliver air at the rate of 12,500 cfm.

Action taken: As a result of a later assessment, it was decided that only four changes per hour would be adequate or 80% of design. As a result, pulley changes were made to reduce fan speed to 915 × .80 = 732 rpm.

Energy/cost savings: Ignoring the potential reduction in energy requirements for heating and cooling, reduction in energy consumption due to lower fan speed = 38,600 Kwh/yr, or an annual dollar saving of $770/year. The following calculations were performed to compute savings:

With the fan speed reduced to 80% of full rating, the power required to drive it is only 50% of full load. Assuming a motor efficiency of 80% at full load,

Power at full load = 9.83 hp × 0.746 Kw/hp × 1/080 = 9.166 Kw.

Assuming a drop in motor efficiency to 77%, Power at 50% load = 9.83 hp × 0.50 × 0.746 Kw/hp × 1/0.77 = 4.762 Kw.

Elec. Power Saving = (9.166 − 4.762) Kw × 8,760 hrs/yr = 38,600 Kwh/yr.

If the cost of electric power is $0.02 per Kwh.

Annual cost saving = 38,600 Kwh/yr × 0.02 $Kwh = $770 per year.

Cost of improvement: Nil.

Recommendation: Determine whether the number of air changes called for in your ventilation system can be reduced while still maintaining acceptable air quality standards within the plant.

Fan speed can be reduced, and energy saved, merely by changing pulleys. However, if the motor operates at less than 50 percent of its rated load, its efficiency may be poor, and, as a result, its power factor unduly high. In some cases a smaller motor rated for the job will produce greater savings. In other cases, correcting the power factor may prove less expensive than installing a smaller motor. The greater the extremity of ambient outdoor temperatures, the greater the potential savings and heating and cooling requirements due to reduced plant or warehouse air changes (see other case history).

Study leads to reduction in outside lighting levels

The situation: An 83-acre shopping centre in the U.S. (with many of the same outdoor lighting porblems as an industrial plant) was concerned with exterior lighting levels and their resulting effect on electrical consumption.

Action taken: A thorough study of lighting requirements was carried out, examining such factors as distribution of the lights, which lights were wired on time clocks, which on photocells, which were wired singly, in pairs or in clusters. As a result of the study, only 1,401 of the previous 2,250 lights are now used to achieve an adequate, but no uniform level of lighting. Parking lot lighting levels were restricted to 2 footcandles.

Energy savings: 56,600 Kwh/month × 12 months = 679,200 Kwh/yr.

Dollar savings: 679,200 Kwh/yr @ $.025/Kwh = $16,980/yr.

Recommendations: Analyze outdoor lighting levels to determine whether use of some lights can be eliminated or rescheduled without going below adequate, safe lighting levels. If your outdoor lights are not yet on photocells or timers, give careful consideration to this option which can reduce power consumption considerably.

"Timed-off" warehouse lighting saves energy

The situation: An 18,000 sq. ft. warehouse at 3M Canada Limited uses 48—8 foot VHO fluorescent fixtures which consume 21.6Kw of power. The warehouse has a very low occupancy. Typically, a lift truck enters the area 20 times a day for five minutes each time.

Action taken: A study of the area indicated that it was occupied only 1.7 hours of each day. After the study was made, a rope switch at each entrance and a ten minute timer were installed to control the "on" time of 45 of the 48 lights.

Energy saved: 45 × .45 Kw × (24—3.3) hrs. × 250 days = 517,500 Kwh/yr.

Dollar savings: Consumption—517,500 × $.01 = $5175.00/yr.

Demand 45 × .45 Kw × $2.25 × 12 mo. = 546.00/yr.

TOTAL $5721.00/yr.

Cost of improvement: $2500.00.

Recommendation: Areas of infrequent occupancy readily lend themselves to automatic controls which ensure conservation that might otherwise not be achieved because of indifference or carelessness.

Because the lights are off most of the time, the installed lamp life is doubled.

Timers on HVAC fans save energy

The Situation: About 130,000 cfm of air is moved

by certain plant, kitchen and toilet exhaust fans, and by office building supply and return fans at 3M Canada's London site. Since the areas served by these fans are unoccupied during the night and on weekends, continuous running of the fans leads to a needless waste of energy.

Action Taken: Seven-day timers were installed on these fans, each timer programmed to control the required run time of the various fans.

Energy Saved: 52,000 gal. oil per year, or 9300 Mcf gas per year, as well as considerable electrical energy due to reduced chiller run time during the summer months.

Dollar Savings: $14,500 per year or $16,000 per year, plus electrical energy savings.

Recommendations: Ventilation or air conditioning fans serving areas which are unoccupied for regular periods of time are a prime application for run-time programming by seven-day timers, eliminating heating and cooling loads when they are not essential to employee comfort.

Turning off plant lights during lunch break cuts consumption

The situation: A company was faced with the problem of continually increasing power bills and decided to attempt to maximize lighting efficiency by turning off lights in the plant during a one hour lunch break. There was concern, however, that savings in electrical energy consumed by the extinguishing of 1000, 110-watt fluorescent bulbs might be outstripped by costs incurred due to shorter lamp life.

Action taken: A detailed study was performed which showed that savings in energy and net costs would be attained under the program proposed. The firm proceeded to turn off plant lights when workers were absent during a lunch break.

Energy/dollar savings: Total cost savings (energy-additional replacement cost) = $548/year. Calculations assumed an electrical energy cost of $.02/Kwh, and a labour replacement cost of $2.00/lamp, and a unit cost per lamp of $2.95, and were performed as follows:

Power savings = 1 hour/day × 250 days/year × 1000 lamps × 120 watts ÷ 1000 watts/Kw. = 30,000 Kwh/yr.

Assuming 10,000 Btu to produce 1 Kwh;
Energy savings = 300 MMBtu/yr.
Cost savings = 30,000 Kwh/yr × $0.02/Kwh. = $600 per year.

The daily cost of replacing a lamp is given by

$= (P = h)(C_1 + C_2)/L$

where

P = the price of a replacement lamp
h = the labour cost for replacing a lamp
L = the average lamp life at 3-hour-per-operating-period
$C_1 C_2$ = the lamp life hours consumed for each daily operating time period (hours/operating period).

For continuous 10 hour operation with the lights left on during the lunch break, $C_1 = 10$ and $C_2 = 0$

Replacement cost = (2.95 + 2.00)(10 + 0)/17,000 hr. = $.0029/lamp-hr. = $.0029/lamp-hr. × 1000 lamps × 250 days/yr × 1 hr/day = $725/year

Suppose the lights are burned for 4.5 hours ($C_1 - 4$), turned off for 1 hour, and then burned for 4.5 hours ($C_2 - 4$)

Replacement cost = (2.95 + 2.00)(4 + 4)/12,000 hr. = $0.0033/lamp-hr. = $0.0033/lamp-hr × 1000 lamps × 250 days/yr × 1 hr/day = $825/year.

Therefore the additional cost of replacement can be estimated: Additional cost = $825 − $773. = $52 per year.

Total cost savings (energy — additional replacement cost) = $600 − $52. = $548 per year.

Cost of improvement: Nil.

Recommendations: Before shutting off lighting in a plant for short, but regular periods, calculate the net savings which can be expected after incurring somewhat shorter lamp life.

Turning out the lights saves energy, fluorescent tubes

The situation: A U.S. plant of more than 100,000 sq. ft. was lit by a total of 2,200 eight foot fluorescent lamps (110-watt plus 10 watt ballast per lamp). Normal practice had been to leave all lights burning Monday through Friday, 24 hrs/day, 50 wks/yr. Management realized that energy savings could be considerable if lights were turned off when the plant was not in use, but was anxious to predict the actual level of

savings which could be expected.

Action taken: A lighting plan was instituted for non-operating hours which provided illumination only for required maintenance and security. The elimination of non-essential lighting resulted in a lighting plan equivalent to burning all lights for 10 hrs/day, 250 days/year.

Energy/dollar savings: An annual power saving of $7,090 was achieved, plus a reduction in lamp replacement cost of $710. total saving = $7,800/yr. Electrical and lamp replacement savings were predicted using the following calculations:
Annual Power Saving = (24-10) h/d × 250 days/yr × 120 w/lamp × 2200 lamps. = 924,000 Kwh per year.
At a cost for electricity of $0.007677 Kwh.
Annual Power Cost Saving = 924,000 Kwh/yr × 0.007677 $/Kwh. = $7,090 per year.
Annual Replacement Cost = (P + h) × (C d/L) × n
Where,

P = price of replacement lamp
h = labour cost of replacing lamps
C = lamp life hours consumed by each operating period (hours per start) as estimated from Figure 1
d = number of operating periods per year
L = average lamp life at specified hours per start
n = number of lamps

For this case the labour cost (h) is $2.00, and the price (P) is $1.42 per lamp with average life (L) of 17,000 and 20,000 hours for 10 hrs/start and 18 hrs/start respectively. As stated previously, there are 2200 lamps (n).
For the old plan, there were 5 days × 24 hours = 120 hours per operating period; C = approx. 60 h. There were 50 operating periods (d) per year.
Replacement = (2.00 + 1.42) $/lamp × 120 h/period × 50 periods × 2200 lamps/20,000 h. = $2,260 per year.
For the new plan there are 250 periods (d) of 10 hours each; C is 7.5 h.
Replacement = (2.00 + 1.42) $/lamp × 7.5 h/period × 250 periods × 2,200 lamps/12,000 h. = $1,170 per year.
Replacement = $1,880 − $1,170. Saving (net) = $710 per year.
Total annual saving = $7,090 + $710. = $7,800 per year.

Recommendation: Turning off lights when the plant is not in use is an obvious money saver. However, it is frequently useful as a motivational tool to be able to tell both top management and employees how much will be saved by the effort. Realistic predictions help sell the program in advance and give all employees a greater sense of pride in energy conservation programs.

Urethane spray re-roof cuts heat loss

The situation: The Toronto plant of Sangamo Limited is comprised of a number of older industrial buildings with both a saw-tooth roof and steam and process pipes and ducts close to the roof. Faced with the necessity of replacing the old roof, the company's energy conservation committee decided to explore alternatives to the previous combination of tar, asphalt and roll roofing.

Action taken: A decision was made to implement a phased program (over several years) to replace the existing roofing with spray urethane material covered by a silicone rubber shell. Based on detailed measurements and calculations, decisions on the thickness of urethane over particular sections of the plant were taken. In general, the company installed 1-inch urethane on 2 x 4 in boards with 1½-inch thick insulation on 1-inch roof planks. The thicker insulation increases cost by about 5 percent. Both offer an overall R-17 insulation factor.

Energy/dollar savings: With just 10 percent of the 189,000 sq. ft. roof completed in the first year, a winter 40 percent colder than normal and a 15% increase in the cost of gas, gas consumption and billing to create steam for plant heating, actually decreased in the first year.

Cost of improvement: When complete, approximately $500,000.

Recommendation: When replacing a plant roof after 20-25 years in place, look to urethane and other new roofing compounds which can substantially reduce roof heat losses. A consultant or roofing contractor will assist in making the correct selection of type and thickness of insulating material. Too great an R factor in the insulation over areas of the plant giving off process heat can result in increased ventilation requirements — and cut into overall energy savings.

Weekend reduction of mine ventilation saves energy

The situation: At Inco Limited's Garson Mine near Sudbury the local energy committee identified a potential saving in electric power and natural gas consumption by reducing mine ventilation on weekends—when diesel powered equipment is not active underground.

Action taken: After a careful check on the effects of reducing ventilation, a schedule for shutting off both fresh air and exhaust fans on the weekends was implemented resulting in shutting down a total of 850 hp of electric fan motors. During winter months, fresh make-up air must be heated and consequently a reduction in natural gas usage to heat this air resulted in additional savings.

Energy savings: Electric power: 1,400,000 Kwh/yr.
Natural gas: 10,000 Mcf/yr.

Dollar savings: 1,400,000 @ 2.5 kwh = $35,000. 10,000 Mcf @ $2.00/Mcf = $20,000. Total = $55,000 year.

Cost of improvement: Nil. A schedule with clear delegation of responsibility for shutdown was all that was required.

Recommendation: Attempt to apply thinking such as that exemplified in the mine example above to the plant situation. Unnecessary ventilation can consume major amounts of plant heat. Caution is required to assure that the working environment will not be impaired.

Wire mesh heating installation reduces heating bills, installation costs

The situation: More than 10 years ago when the management of Phillips Cables Limited constructed a new plant in Rimouski, Quebec, they opted for a then new heating system—utilizing the reinforcing mesh in the concrete floor as the heating system—radiating heat created by low voltage off-peak electrical energy. As a prototype installation, installation of detectors at points inside and outside the factory was undertaken to record temperatures (see chart). The plant is 31,600 sq. ft. in the area, 620,000 cu. ft. in volume, and is constructed of cement blocks. The area around Rimouski experiences an average of 9,700 degree days per year.

Action taken: Due to the large amount of electric motive power required to operate the plant, the company was able to install a wire mesh electric heating system in which a power input of 24 volts is fed through copper rods soldered to the reinforcing bars and connected to the transformer secondaries. A 10-watt load is provided for and 4 thermostats located around the plant control temperature. The system is controlled, along with other electrical loads in the plant by peak demand control system. Readings taken during the heating season have established that floor temperature remains at 80°F and the ambient temperature in the plant remains between 70° and 74°F. Electric baseboard heaters are used in adjoining offices and five force flow unit heaters provide rapid heat recovery when doors to the plant are opened.

Operating cost: Heating of the plant is accomplished by a yearly output of only 413,000 Kwh. @ 2.5¢ Kwh = $10,325./yr or less than 33¢/sq. ft.

Cost of improvement: Original installation of electricity and mechanics (1968) $3.45 sq. ft.

Recommendation: For new installations—and retrofit of those few plants where new flooring is needed or where wire mesh has a decided economic advantage and good access to the floor area can be provided—consider use of wire mesh heating systems. For many applications, in conjunction with load shedding controllers, this system offers energy efficient low cost heating.

Wire mesh retrofit replaces waste fired space-heating

The situation: Due to environmental regulations, the sawmill and planing mill operated at Luceville, P.Q. by Luceville Lumber Limited was forced to stop burning sawdust, bark and chips. The waste materials were all sold to a neighbouring paper mill, but a new way had to be found to heat the sawmill, the planing mill and kilns.

Action taken: The company decided to go with electric power. Both the kiln and the sawmill were connected to electric resistance heating.

However, in the planing mill, the concrete floor had to be redone and since there was enough room "in the alleys" it was decided that a low-voltage (15 w/sq. ft.) wire mesh heating system could be retrofitted. All were controlled by an automatic demand control system to minimize peak electrical loads.

Energy/Dollar savings: Not available

Cost of improvement: 18,000 sq. ft. × 15 w/sq. ft @ $1.50/sq. ft. = $27,000/year

Recommendation: Wire mesh heating is generally better suited to original installations; however, do not dismiss it out of hand as a possibility for retrofit installations.

Tips for saving money in Heating, Cooling and Lighting

General

1. Reduce ventilation and exhaust rates where possible.
2. Close off all unused openings and stacks.
3. Repair all broken windows, skylights and doors.
4. Eliminate unnecessary windows or replace single pane windows with double pane glass.
5. Weatherstrip windows and doors; caulk or otherwise eliminate cracks in the building envelope.
6. Insulate wherever possible.
7. Lower building thermostat settings during the heating season and raise them in the cooling season to the greatest extent possible.
8. Eliminate heating or cooling from all unused buildings or rooms.
9. Install window shades or reflective coatings to reduce heat gain from summer sun.
10. Utilize trees and shrubs as sun shades and wind breaks.
11. Utilize effective colours inside and outside the plant for reflection of light and solar radiation.
12. Encourage employees to wear heavier or lighter clothing during the heating or cooling seasons to accommodate the new thermostat settings.
13. Consider infra-red heaters in high bay areas and warehouses.
14. Utilize ceiling fans to reduce heat stratification.
15. Recycle air for heating, ventilation and air conditioning to the maximum extent.
16. Replace air curtain doors with solid doors.
17. Interlock heating and air conditioning systems to prevent simultaneous operation.
18. Check with equipment suppliers or qualified engineers to determine the extent to which equipment is oversized. Occasionally one boiler in a multiboiler system can be eliminated by more efficient use of the others.

Heating Systems

1. Assure that heating equipment is in good operating condition; regularly clean all air intakes and heat transfer surfaces.
2. Install heat recovery devices in all outgoing ventilation ducts to heat incoming air.
3. Install automatic ignition devices where gas pilot lights are used.
4. Do not allow the use of portable space heaters in office areas.
5. Install automatic door closers, revolving doors or loading dock shelters to prevent incursion of outside air.
6. Lower the thermostat setting in the heating season. Each degree lower saves roughly 2½ per cent more energy.
7. Set thermostats even lower at night and on weekends. Utilize dual thermostat systems to make lower settings automatic.
8. Lower washroom water temperatures.
9. Concentrate after hours group employee work in one heated area to permit thermostats to be lowered in most of the plant.
10. Consider modifying humidity levels to increase comfort levels at lower temperatures.
11. Discontinue humidity controls during non-working hours.
12. Operate ventilation systems only when necessary, not on a continuous basis.
13. Encourage the wearing of heavier clothing

and permit women employees to wear slacks as the temperature is lowered in the office.

14. Keep all air grills clean.
15. Heat water during off peak periods and store in well insulated vessels for later use.
16. Heat service hot water with air conditioning compressor exhaust.
17. Use a heat wheel, heat pipe or other heat exchanger to cross-exchange building exhaust air with make-up air.
18. Look to air cooled compressor exhaust as a source of usable heat.

Air conditioning

1. Turn off air conditioning in all unoccupied areas.
2. Ensure that the air conditioning system is in good working order; keep filters, coils and blowers clean.
3. Use spot coolers when spaces are occupied only at various and irregular times.
4. Restrict employee smoking to reduce ventilation requirements.
5. Clean refrigerant condensors to reduce compressor horsepower.
6. Utilize humidity controlling systems which will allow humidity to rise to the highest acceptable setting — systems that use reheat are particularly beneficial.
7. Minimize heat created by lights, machinery or equipment which are left "on" when not required.
8. Leave storm doors and windows in place during the summer to prevent outside heat from coming in.
9. Use water cooled lighting fixtures if possible.
10. If the office is completely vacated after normal closing hours, turn off air conditioning at least one hour before quitting time.
11. If possible, use heat-producing equipment such as photocopiers in the early morning or later afternoon.
12. Use awnings or shades to reduce heat gain from insolation.
13. Urge employees to wear lighter clothing to accommodate themselves to slightly higher office or plant temperatures.
14. Consider a spraying system or other means of evaporating water on the roof to reduce air conditioning load.
15. Size air handling grills, ducts and coils to minimize air resistance.

Lighting

1. Turn off all unnecessary lights.
2. Replace low efficiency light sources with fluorescent, mercury, sodium or high intensity direct lighting.
3. Keep bulbs and fixtures clean and free of light-blocking dirt.
4. Selectively remove lights — and ballasts — where lighting levels exceed established standards.
5. Reduce or eliminate decorative lighting.
6. Install photocells to control outdoor or perimeter lighting.
7. Utilize direct sunlight as a source wherever possible.
8. Lower wattage of lighting where possible.
9. Use light colours on ceilings and walls, floors and furnishings.
10. Install timers on lights in little used areas of the plant.
11. Use automatic switches to assure that plant lighting is extinguished after the last shift leaves.
12. Provide light switches in office areas so that individual lights may be turned off.
13. Place lighting switches in prominent places.
14. Move to "task lighting" wherever possible.
15. Eliminate inefficient electric lamps from plant stocks and catalogs.
16. Consider turning off plant lights during lunch breaks.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg{\cdot}m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1° = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY THROUGH PROCESS DESIGN AND HEAT RECOVERY 3

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Office of Energy Conservation
Bureau de la conservation de l'énergie

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SAVING MONEY THROUGH PROCESS DESIGN AND HEAT RECOVERY 3

Saving money through Process Design and Heat Recovery

Introduction:

Most of the industrial processes in Canadian plants of today were designed in a period when energy costs and attitudes toward energy usage were vastly different. As a result, many processes are tremendously energy inefficient.

This booklet is designed to help plant manager to more efficiently utilize process equipment and to retrofit insulation, controls and other equipment which will promote greater conservation of electrical and other energy.

And while heat recovery techniques cover a wide spectrum of industrial areas, many are process related. As a result, the text contains a full description of various heat recovery devices commercially available.

Process design and heat recovery

High energy costs — they're something industry has come to accept as an immutable fact of life. In fact, we've come to take them so much for granted that its sometimes hard to remember when energy costs were much lower than they are now.

But those times are not ancient history. The substantial increase in energy costs is really a fairly recent phenomenon. As late as 1972, for example, most Canadian companies were paying less than $1.00 for an Mcf of natural gas. It should come as no surprise then, that most plants, even those which can be classified as "modern" were designed with easily available, relatively low cost fuel as a basic parameter. As a result, many facets of plant energy utilization are not as energy efficient as they might be. Heating, lighting, steam systems and production planning, among other areas, all reflect an attitude towards energy and its utilization which emphasized growth without really worrying about a contribution to cost savings through conservation of energy.

Nowhere is this attitude more apparent than in the area of plant processes and equipment. Simply stated, if energy costs had been at their present levels and energy conservation had been a watchword, processes would not have been designed in the way that they were — without adequate insulation, allowing large quantities of waste heat to escape and ignoring other sources of waste heat for preheating of process materials.

There is no point in belabouring the fact that the ground rules have changed. A more productive concern is one about what can be done to rectify the situation which exists in many plant processes.

In addition, water has a large quantity of energy indirectly associated with its treatment and supply. As well, waste water often contains significant quantities of energy.

In future, water will not only be progressively more costly to procure in large quantities, it will be more costly to dispose of. Water conservation programmes can be justified now on the basis of economics (see case histories); but they will also stand companies in good stead should water "curtailment" or at least stringent supply controls become a reality.

Identifying the magnitude of the opportunity

The degree to which processes in a given plant are efficient or inefficient will depend largely on when the plant was built, when various processes were installed and the degree of energy enlightenment that was shown by engineers and designers at the time of installation.

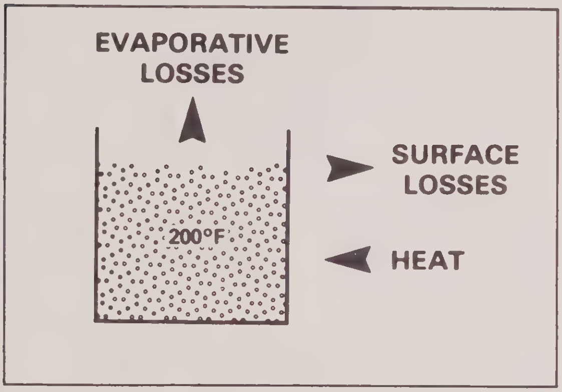
Most managers think they have a good "gut" feeling for general areas of energy inefficiency in plant processes. But often there is a great surprise as to where the major energy losses really do occur. These can only be revealed in a comprehensive energy audit.

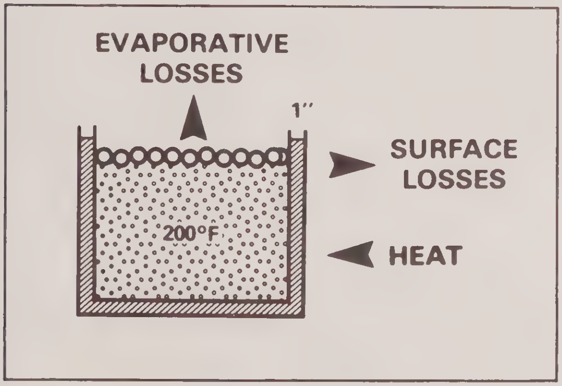
The process of conducting an energy audit is covered in some detail in the Guidebook to the OEC handbook series. However, there are

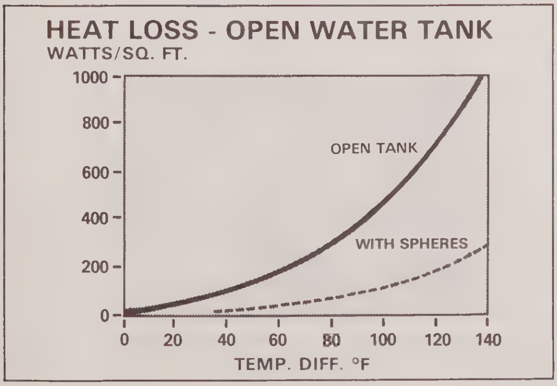
several basic steps to the process audit which should be mentioned:

- Look first at processing operations to establish priorities based on where substantial quantities of energy are involved.
- Wherever possible measure energy flows and process and effluent temperatures.
- Re-examine consultants' and manufacturers' specifications to see if these are being met.

Heat losses from process tanks







- Analyze each process using a simplified block diagram to show energy and material balances.

Perhaps most fundamental to a successful assessment of the system is a questioning (and cynical) mind. It is essential that questions be asked and the parameters of each process not simply be accepted as "the way things are" or "the way we do it around here".

Among the fundamental questions which must be asked are:

- Are process maintenance practices up to scratch? Or are they resulting in increased energy consumption?
- Can temperatures, flow rates or other conditions affecting energy consumption be lowered without affecting production rates or product quality?
- Could the equipment be better insulated to reduce heat losses?
- Can heat losses from the process be recirculated to preheat process input?
- Are there other sources of waste heat around the plant which can be used for preheating material for the process?
- Are there any waste materials which could be converted into useful energy?

Manufacturers of equipment, chemicals and additives can often be of great help here — and a little experimentation may be required before the ideal balance between product quality and energy conservation is struck — but energy savings will make the effort worthwhile.

With proper design, product quality does not have to be sacrificed to energy expediency. For example, in one case history, a one coat painting system was designed for tractor parts, saving considerable amounts of energy in drying ovens.

In the parlance of the day, "small is beautiful". The less processing that is done at high temperatures, the lower the energy requirements and the fewer the problems that will exist for disposal of the hot effluent. However, two factors in energy are temperature and time. Some processes operating at very high temperatures for short periods may use less energy than alternative processes at lower temperatures for longer times (e.g. Ultra High Temperature Milk).

Heat, and often high heat, is frequently a necessity for industrial processes and today's economics have made it a basic law of thermodynamics that "wherever there is heat there should be insulation".

Here, open baths for plating and other processes are an excellent example. Case histories in this booklet demonstrate graphically the potential uses for insulation on tank bottoms and sides and for the use of either a floating blanket of plastic balls or moveable rigid covers. Not only does a complete insulation system of this sort save substantial amounts of energy, it cuts down on evaporation — reducing water requirements and reducing the deleterious affects on both people and equipment of a moist ambient environment.

Insulation of another sort is involved with air curtains and other means of reducing steam and vapour losses from process equipment, without the need for excessive exhausts to create negative pressures inside the washer. Keeping in the vapour, in these examples (see case history), means keeping the heat in — and will save energy.

Air gases also often convey energy — and it is important to control their flow.

Waste not, want not

It goes without saying that an effort should be made in all processes to waste as little as possible. If effluent can be filtered and re-used as part of the process — so much the better. Great strides have been made recently in the use of reverse osmosis and other techniques which can greatly reduce the amount of process waste which once had to be trucked away for disposal. This is not the technology of ten years from now . . . investments can be justified today, in many cases, on the strength of the savings that can be made.

But even if the effluent doesn't incur the costs of trucking for disposal, why waste it — or use it on a once through basis — if it can be recirculated? The booklet in this series on "Steam Management" extols at some length the virtues of condensate recovery for boilers. And the same type of reasoning applies to process applications.

Among the commodities most often wasted needlessly, water probably heads the list. Heated water of all kinds is frequently flushed to sewer after one use. In many cases the water can be used directly in another process as feedwater. In others it can be used in a heat exchanger to extract much of the sensible heat before it's diposed of. In still others where it has gained a great deal of heat and heat is not required, it can be put through a cooling tower and re-used (see case history).

There are amazing parallels which can be drawn between water and energy conservation. Both commodities were once thought to be abundant and cheap and thus were wasted. Water has not yet made the "endangered species" list along with energy. But it's not far behind and smart business judgment — and in some cases municipal controls — dictate that it should be conserved wherever possible.

Heat recovery — the great frontier

Imagination is a great asset to anyone examining energy use in process applications. The range of remedial measures or new designs that are possible are almost boundless. And for each basic application, there are a hundred small modifications which may need to be made to meet the specific conditions of a given plant.

With the assumption that process equipment is well designed, maintained and operated, another major subject area — heat recovery — is opened up. In fact, its scope is so large that an attempt has not been made to cover it all in one booklet. To mention just a few, there are heat recovery schemes where flue gas heat is used to preheat building make-up air, where oven exhaust is used to preheat oven entering air, and where flash steam is used to heat air or a number of products. The list is a long one.

For the sake of organization, case histories on the subject have been divided up on the basis of the area they effect most directly to appear in booklets two, three, five or six in this series.

Those pertaining to flash steam or condensate recovery are generally in the "steam" booklet; those pertaining to space heating examples are generally found in the booklet on "Heating, Lighting and Air Conditioning"; those related to combustion are found in the "Combustion Control" booklet; etc. A look at the index is the best guide as to where to find information relevant to specific interests.

In this booklet, case histories generally pertain to heat recovery where heat is either taken from or supplied to industrial process. In addition, an attempt will be made to list the major generic types of heat recovery equipment now available on the market.

At the outset, though, it should be pointed out that the most efficient heat recovery systems are those where there is no heat exchange medium used. While certain heat exchangers can attain efficiency rates of 80 percent and more in given settings, none can compete with direct recycling when this can be accomplished.

Where, for example, clean flue gases from a dryer in a wash process can be ducted directly to the strip section to pre-dry metal parts, thermal efficiency gets as close to 100% as it can. Similarly, where hot air from any source can be filtered or cleaned by electrostatic precipitation and used to heat building air, efficiency will be greater than that attainable by heat recuperation using mechanical means.

This is particularly true, for example with cooling water from air compressors or spot welders which is most profitably used as feedwater for boilers, wash processes or other direct applications. And steam condensate is generally most economically returned to the boiler for recycling once it has given up its flash steam for use in low pressure steam systems or other applications.

For obvious reasons, though, not all sources of waste heat can be recirculated directly. In many cases, there are contaminants in the hot gas or liquid which cannot be removed simply or at low cost and heat reclaiming equipment is a necessity.

Options in heat recovery equipment

Industrial heat exchangers have many pseudonyms. They are sometimes called recuperators, regenerators, waste heat steam generators, condensers, heat wheels, temperature and moisture exchangers, and other names. Whatever name they many have, they all perform one basic function, the transfer of heat.

Heat exchangers are characterized as single or multipass gas to gas, liquid to gas, liquid to liquid, evaporator, condenser, parallel flow, counter flow, or cross flow. The terms single or multipass refer to the heating or cooling media passing over the heat transfer surface once or a number of times. Multipass flow involves the use of internal baffles. The next three terms refer to the two fluids between which heat is transferred in the heat exchanger, and imply that no phase changes occur in those fluids. Here the term "fluid" is used in the most general sense. But all these terms apply to nonevaporator and noncondensing heat exchangers.

The term evaporator applies to a heat exchanger in which heat is transferred to an evaporating (boiling) liquid, while a condenser is a heat exchanger in which heat is removed from a condensing vapor. A parallel flow heat exchanger is one in which both fluids flow in approximately the same direction whereas in counterflow the two fluids move in opposite directions. When the two fluids move at right angles to each other, the heat exchanger is of the crossflow type.

The principal methods of reclaiming waste heat in industrial plants make use of heat exchangers. In essence, a heat exchanger is a system which separates the stream containing waste heat and the medium which is to absorb it, but allows the flow of heat across the separation boundaries. The reasons for separating the two streams may be any of the following:

- A pressure difference may exist between the two streams of fluid. The rigid boundaries of the heat exchanger can be designed to withstand the pressure difference.
- In many, if not most, cases the one stream would contaminate the other, if they were permitted to mix. The heat exchanger prevents mixing.
- Heat exchangers permit the use of an intermediate fluid better suited than either of the principal exchange media for transporting waste heat through long distances. The secondary fluid is often steam, but another substance may be selected for its special properties.
- Certain types of heat exchangers, specifically the dessilant heat wheel, are capable of transferring humidity as well as heat. Vapors being cooled in the gases are condensed in the wheel and later re-evaporated into the gas being heated. This can result in improved humidity and / or process control, abatement

of atmospheric air pollution, and conservation of valuable resources.

The various names or designations applied to heat exchangers are partly an attempt to describe their function and partly the result of tradition within certain industries. For example, a recuperator is a heat exchanger which recovers waste heat from the exhaust gases of a furnace to heat the incoming air for combustion. This is the name used in both the steel and the glass making industries. The heat exchanger performing the same function in the steam generator of an electric power plant is termed an air preheater, and in the case of a gas turbine plant, a regenerator.

However, in the glass and steel industries, the word regenerator refers to two chambers of brick checkerwork which alternately absorb heat from the exhaust gases and then give up part of that heat to the incoming air. The flows of flue gas and of air are periodically reversed by valves so that one chamber of the regenerator is being heated by the products of combustion while the other is being cooled by the incoming air. Regenerators are often more expensive to buy and maintain than recuperators, and their application is primarily in glass melt tanks and in open hearth steel furnaces.

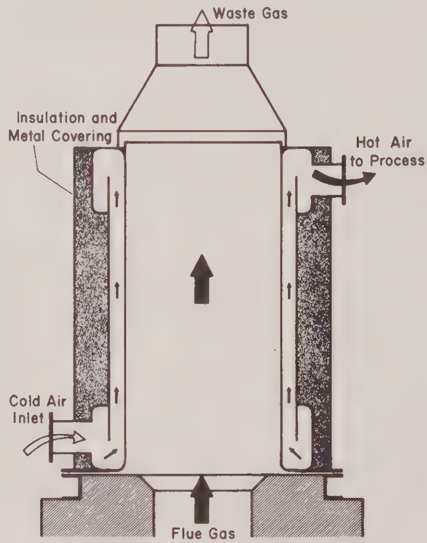
It must be pointed out, however, that although their functions are similar, the three heat exchangers mentioned may be structurally quite different as well as different in their principal modes of heat transfer. A more complete description of the various industrial heat exchangers follows later in this chapter and details of their differences will be clarified.

The specification of an industrial heat exchanger must include the heat exchange capacity, the temperature of the fluids, the allowable pressure drop in each fluid path, and the properties and volumetric flow of the fluids entering the exchanger. These specifications will determine construction parameters and thus the cost of the heat exchanger. The final design will be a compromise between pressure drop, heat exchanger effectiveness, and cost. Decisions leading to that final design will balance out the cost of maintenance and operation of the overall system against the fixed costs in such a way as to minimize the total. Advice on selection and design of heat exchangers is available from vendors.

The essential parameters which should be known in order to make an optimum choice of waste heat recovery devices are:

- Temperature of waste heat fluid
- Flow rate of waste heat fluid
- Chemical composition of waste heat fluid
- Minimum allowable temperature of waste heat fluid
- Temperature of heated fluid
- Chemical composition of heated fluid
- Maximum allowable temperature of heated fluid
- Control temperature, if control required.

Metallic radiation recuperator



Gas to gas heat exchangers

1. Recuperators

The simplest configuration for a heat exchanger is the metallic radiation recuperator which consists of two concentric lengths of metal tubing as shown.

The inner tube carries the hot exhaust gases while the external annulus carries the combustion air from the atmosphere to the air inlets of the furnace burners. The hot gases are cooled by the incoming combustion air which

now carries additional energy into the combustion chamber. This is energy which does not have to be supplied by the fuel; consequently, less fuel is burned for a given furnace loading.

The saving in fuel also means a decrease in combustion air and therefore, stack losses are decreased not only be lowering the stack gas temperatures, but also by discharging smaller quantities of exhaust gas. This particular recuperator gets its name from the fact that a substantial portion of the heat transfer from the hot gases to the surfact of the inner tube take place by radiative heat transfer. The cold air in the annulus, however, is not affected by infrared radiation so that only convection heat transfer takes place to the incoming air.

As shown in the diagram, the two gas flows are usually parallel, although the configuration would be simpler and heat transfer more efficient if the flows were opposed in direction (or counterflow). The reason for the use of parallel flow is that recuperators frequently serve the additional function of cooling the duct carrying away the exhaust gases, and consequently extending its service life.

The inner tube is often fabricated from high temperature materials such as stainless steels of high nickel content. This gives a large temperature differential expansion, since the outer shell is usually of a different and less expensive material. And the mechanical design must take this effect into account. More elaborate designs of radiation recuperators incorporate two sections; the bottom operating in parallel flow and the upper section using the more efficient counterflow arrangement. Because of the large axial expansions experienced and the stress conditions at the bottom of the recuperator, the unit is often supported at the top by a free standing support frame with an expansion joint between the furnace and recuperator.

A second common configuration for recuperators is the tube type or convective recuperator. As seen in the schematic diagram, the hot gases are carried through a number of parallel small diameter tubes, while the incoming air to be heated enters a shell surrounding the tubes and passes over the hot tubes one or more times in a direction normal to their axes.

If the tubes are baffled to allow the gas to pass over them twice, the heat exchanger is termed a two-pass recuperator; if two baffles are used, a three-pass recuperator, etc. Although baffling increases both the cost of the exchanger and the pressure drop in the combustion air path, it increases the effectiveness of heat exchange. Shell- and tube-type recuperators are generally more compact and have a higher effectiveness than radiation recuperators, because of the larger heat transfer area made possible through the use of multiple tubes and multiple passes of the gases.

The principal limitation on the heat recovery of metal recuperators is the reduced life of the liner at inlet temperatures exceeding 2000°F. At this temperature, it is necessary to use the less efficient arrangement of parallel flows of exhaust gas and coolant in order to maintain sufficient cooling of the inner shell. In addition, when furnace combustion air flow is dropped back because of reduced load, the heat transfer rate from hot waste gases to preheat combustion air becomes excessive, causing rapid surface deterioration. Then, it is usually necessary to provide an ambient air by-pass to cool the exhaust gases.

In order to overcome the temperature limitations of metal recuperators, ceramic tube recuperators have been developed, whose materials allow operation on the gas side to 2800°F and on the preheated air side to 2200°F on an experimental basis, and to 1500°F on a more or less practical basis. Early ceramic recuperators were built of tile and joined with furnace cement, and thermal cycling caused cracking of joints and rapid deterioration of the tubes. Later developments introduced various kinds of short silicon carbide tubes which can be joined by flexible seals located in the air headers. This kind of patented design illustrated maintains the seals at comparatively low temperatures and has reduced the seal leakage rates to a few percent.

Earlier designs had experienced leakage rates from 8 to 60 percent. The new designs are reported to last two years with air preheat temperatures as high as 1300°F, and much lower leakage rates.

An alternative arrangement for the convective type recuperator, in which the cold combustion air is heated in a bank of parallel vertical tubes

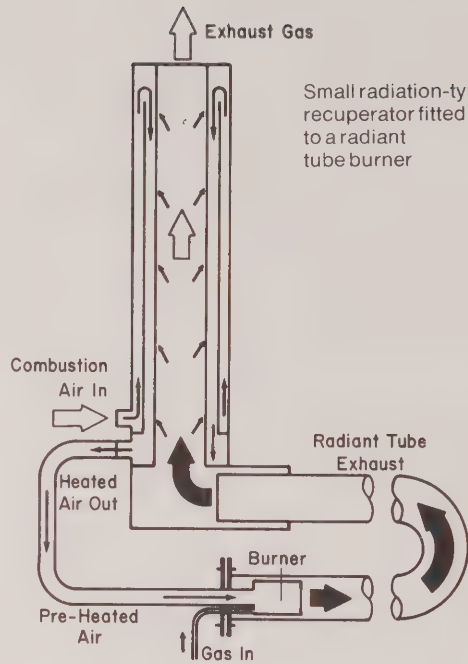
which extend into the flue gas stream, is also shown schematically. The advantage claimed for this arrangement is the ease of replacing individual tubes, which can be done during full capacity furnace operation. This minimizes the cost, the inconvenience, and possible furnace damage due to a shutdown forced by recuperator failure.

For maximum effectiveness of heat transfer, combinations of radiation type and convective type recuperators are used, with the convective type always following the high temperature radiation recuperator.

Although the use of recuperators conserves fuel in industrial furnaces, and although their original cost is relatively modest, the purchase of the unit is often just the beginning of a somewhat more extensive capital improvement program. The use of a recuperator, which raises the temperature of the incoming combustion air, may require purchase of high temperature burners, larger diameter air lines with flexible fittings to allow for expansion, cold air lines for cooling the burners, modified combustion controls to maintain the required air/fuel ratio despite variable recuperator heating, stack dampers, cold air bleeds, controls to protect the recuperator during blower failure or power failures, and larger fans to overcome the additional pressure drop in the recuperator. It is vitally important to protect the recuperator against damage due to excessive temperatures, since the cost of rebuilding a damaged recuperator may be as high as 90 percent of the initial cost of manufacture and the drop in efficiency of a damaged recuperator may easily increase the fuel costs by 10 to 15 percent.

The schematic diagram shows a radiant tube burner fitted with a radiation recuperator. With such a short stack, it is necessary to use two annuli for the incoming air to achieve reasonable heat exchange efficiencies.

Recuperators are used for recovering heat from exhaust gases to heat other gases in the medium to high temperature range. Some typical applications are in soaking ovens, annealing ovens, melting furnaces, afterburners and gas incinerators, radiant-tube burners, reheat furnaces, and other gas to gas waste heat recovery applications in the medium to high temperature range.

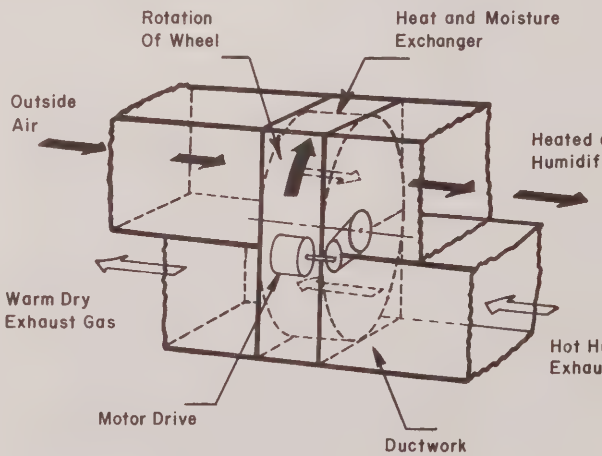


Small radiation-type recuperator fitted to a radiant tube burner

2. Heat wheels

A rotary regenerator (also called an air preheater or a heat wheel) is finding increasing applications in low to medium temperature waste heat recovey. As shown in the sketch, it is a sizable porous disc, fabricated from material having a fairly high heat capacity, which rotates between two side-by-side ducts; one a cold air

Heat and moisture recovery using a heat wheel type regenerator



duct, the other a hot air duct. The axis of the wheel is located parallel to, and on the partition between the two ducts. As the wheel slowly rotates, sensible heat (and in some cases, moisture containing latent heat) is transferred to the material by the hot air and removed from the material by the cold air.

The overall efficiency of sensible heat transfer can be as high as 80 percent and heat wheels have been built as large as 12 ft in diameter with air capacities up to 60,000 cfm. Multiple units can be used in parallel. In very large installations such as those required for preheating combustion stations, the units are custom designed.

Heat wheels are available in four types. The first consists of a metal frame packed with a core of knitted mesh stainless steel or aluminum wire, resembling that found in the common metallic kitchen pot scraper; the second, called a laminar wheel, is fabricated from corrugated metal and is composed of many parallel flow passages; the third type is also a laminar wheel but is constructed from a ceramic matrix or honeycomb configuration. This is used for higher temperature applications with a present-day limit of about 1600°F. The fourth variety is a laminar construction, but the flow passages are coated with a hydroscopic or dessicant material so that latent heat may be recovered. The packing material of the dessicant wheel may be any of a number of materials.

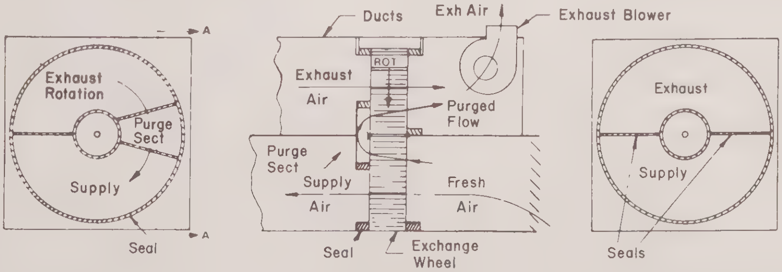
Most industrial stack gases contain water vapor, since water vapor is a product of the combustion of all hydrocarbon fuels and since water is introduced into many industrial processes and part of the process water evaporates as it is exposed to the hot gas stream. Each pound of water requires approximately 1000 Btu for its evaporation at atmospheric pressure, thus each pound of water vapor leaving in the exit stream will carry 1000 Btu of energy with it. This latent heat may be a substantial fraction of the sensible energy in the exit gas stream. A hygroscopic material such as lithium chloride readily absorbs water vapor and in a hygroscopic heat wheel, the hot gas stream gives up part of its water vapor to the lithium chloride coating; the cool gases which enter the wheel to be heated are drier than those in the outlet duct and part of the absorbed water is given up to the incoming gas stream. The latent heat of the water adds directly to the total quantity of recovered waste heat. The efficiency of recovery of water vapor can be as high as 60 percent.

Since the pores of heat wheels carry a small amount of gas from the exhaust to the intake duct, cross contamination can result. If this contamination is undesirable, the carryover of exhaust gas can be partially eliminated by the addition of a purge section where a small amount of clean air is blown through the wheel and then exhausted to the atmosphere, thereby clearing the passages of exhaust gas. The drawing illustrates the features of an installation using a purge section.

When operating with outside air in periods of high humidity and sub-zero temperatures, heat wheels may require preheat systems to prevent frost formation. When handling gases which contain water-soluble, greasy or adhesive contaminants or large concentrations of process dust, air filters may be required in the exhaust system upstream from the heat wheel.

One application of heat wheels is in space heating situations where unusually large quantities of ventilation air are required for health or safety reasons. As many as 20 or 30 air changes per hour may be required to remove toxic gases or to prevent the accumulation of

Heat wheel equipped with purge section to clear contaminants from the heat transfer surface



Building Side (Inside Face)
Upstream Exhaust
(Downstream Supply)

Vertical Cross Section (A-A)
Wheel, Seals and
Purge Section

Weather Side (Outside Face)
Downstream Exhaust
(Upstream Supply)

explosive mixtures. Comfort heating for that quantity of ventilation air is frequently expensive enough to make the use of heat wheels economical. In the summer season the heat wheel can be used to cool the incoming air from the cold exhaust air, reducing the air conditioning load by as much as 50 percent.

It should be pointed out that in many circumstances where large ventilating requirements are mandatory, a better solution than the installation of heat wheels may be the use of local ventilation systems to reduce the hazards.

Heat wheels are finding increasing use for process heat recovery in low and moderate temperature environments. Typical applications would be curing or drying ovens and air preheaters in all sizes for industrial and utility boilers.

3. Air Preheaters. (Parallel plate)

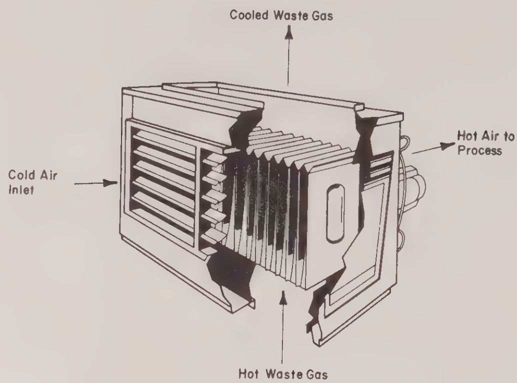
Passive gas to gas regenerators, sometimes called air preheaters, or baffle plate exchangers, are available for applications which cannot tolerate any cross contamination. They are constructed of alternate channels which put the flows of the heating and the heated gases in close contact with each other, separated only by a thin wall of conductive metal. They occupy more volume and are more expensive to construct than are heat wheels, since a much greater heat transfer surface area is required for the same efficiency.

One advantage, besides the absence of cross-contamination, is the decreased mechanical complexity since no drive mechanism is required. However, it becomes more difficutl to achieve temperature control with the passive regeneration and, if this is a requirement, some of the advantages of its basic simplicity are lost.

Gas-to-gas regenerators are used for recovering heat from exhaust gases to heat other gases in the low to medium temperature range. Among typical applications are:

- Heat recovery from building heating and ventilation systems
- Reduction of building air conditioner loads
- Heat recovery from steam boiler exhaust gases

A passive gas to gas regenerator



- Heat recovery from gas and vapor incinerators
- Heat recovery from baking, drying, and curing ovens
- Heat recovery from gas turbine exhausts
- Heat recovery from other gas-to-gas applications in the low through high temperature range

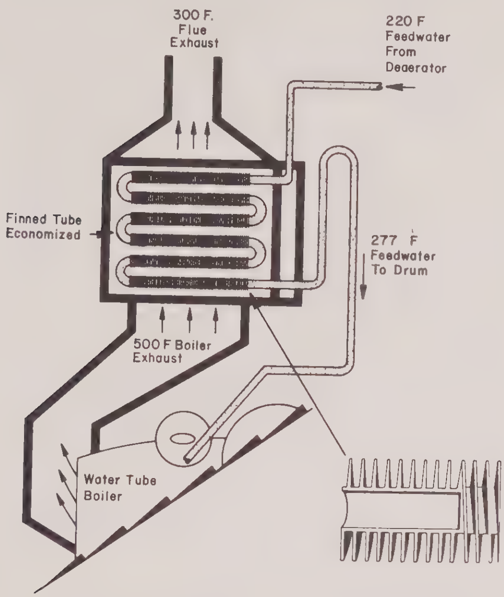
4. Heat pipe exchangers

The heat pipe is a heat transfer element that has only recently become commercial, but it shows promise as an industrial waste heat recovery option because of its high efficiency and compact size. In use, it operates as a passive gas-to-gas finned-tube regenerator. As can be seen in the drawing, the elements form a bundle of heat pipes which extend through the exhaust and inlet ducts in a pattern that resembles the structured finned coil heat exchangers. Each pipe, however, is a separate sealed element consisting of an annular wick on the inside of the full length of the tube, in which an appropriate heat transfer fluid is sealed.

Heat absorbed from hot exhaust gases evaporates the entrained fluid, at one end causing the vapor to move to the other end. The latent heat of vaporization is carried in the vapor to the cold end of the heat pipe located in the cold gas duct. Here the vapor condenses giving up its latent heat. The condensed liquid is then carried by capillary (and/or gravity) action back to the hot end where it is recycled.

Used as designed, the heat pipe is compact and efficient because the finned-tube bundle is inherently a good configuration for convective

Burned tube gas to liquid regenerator (economizer)



heat transfer in both gas ducts and the evaporative-condensing cycle within the heat tubes is a highly efficient way of transferring the heat internally. It is also free from cross contamination. Possible applications include:

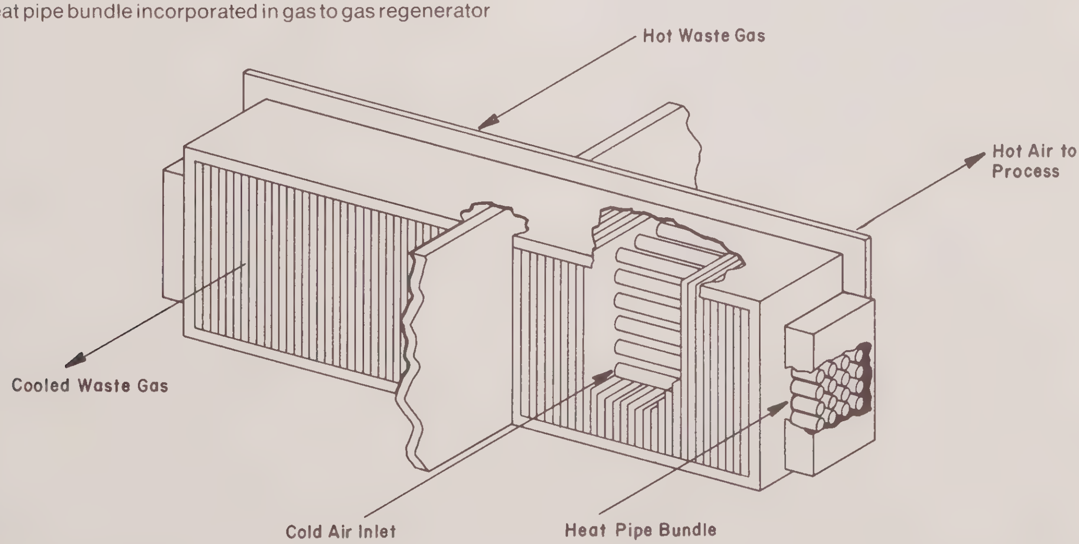
- Drying, curing and baking ovens (recycling waste heat).
- Reclamation of heat from water steam.
- Preheating combustion air from boilers.
- Air dryers.
- Brick kilns (secondary recovery).
- Reverberatory furnaces (secondary recovery).
- Reducing load in heating, ventilating and air conditioning systems.
- Cooling dies and bearings.
- Transferring engine exhaust to carburetor air intake.

Gas or liquid to liquid regenerators

1. Finned-tube Heat Exchangers

When waste heat in exhaust gases is recovered for heating liquids for purposes such as providing domestic hot water, heating the feedwater for steam boilers, or for hot water space heating, the finned-tube heat exchanger is generally used. Round tubes are connected together in bundles to contain the heated liquid and fins are welded or otherwise attached to the outside of the tubes to provide additional surface area for removing the waste heat in the gases. The drawing shows the usual arrangement for the finned-tube exchanger positioned in a duct and details of a typical finned-tube construction. This particular type of application is more commonly known as an "economizer." The tubes are often connected all in series but can also be arranged in series-parallel bundles to control the liquid side pressure drop. The air side

Heat pipe bundle incorporated in gas to gas regenerator



pressure drop is controlled by the spacing of the tubes and the number of rows of tubes within the duct.

Finned-tube exchangers are available prepackaged in modular sizes or can be made up to custom specifications from standard components. Temperature control of the heated liquid is usually provided by a bypass duct arrangement which varies the flow rate of hot gases over the heat exchanger. Materials for the tubes and the fins can be selected to withstand corrosive liquids and/or corrosive exhaust gases.

Finned-tube heat exchangers are used to recover waste heat in the low to medium temperature range from exhaust gases for heating liquids. Typical applications are hot water heating, heating boiler feedwater, hot water space heating, absorption-type refrigeration or air conditioning, and heating process liquids.

2. Shell and Tube Heat Exchanger

When the medium containing waste heat is a liquid or a vapor which can heat another liquid, the shell and tube heat exchanger must be used since both paths must be sealed to contain the pressures of their respective fluids. The shell contains the tube bundle, and usually internal baffles, to direct the fluid in the shell over the tubes in multiple passes. The shell is inherently weaker than the tubes so that the higher pressure fluid is circulated in the tubes while the lower pressure fluid flows through the shell.
When a vapor contains the waste heat, it usually condenses, giving up its latent heat to the liquid being heated. In this application, the vapor is almost invariably contained within the shell. If the reverse is attempted, the condensation of vapors within small diameter parallel tubes causes flow instabilities. Tube and shell heat exchangers are available in a wide variety of standard sizes with many combinations of materials for the tubes and shells.

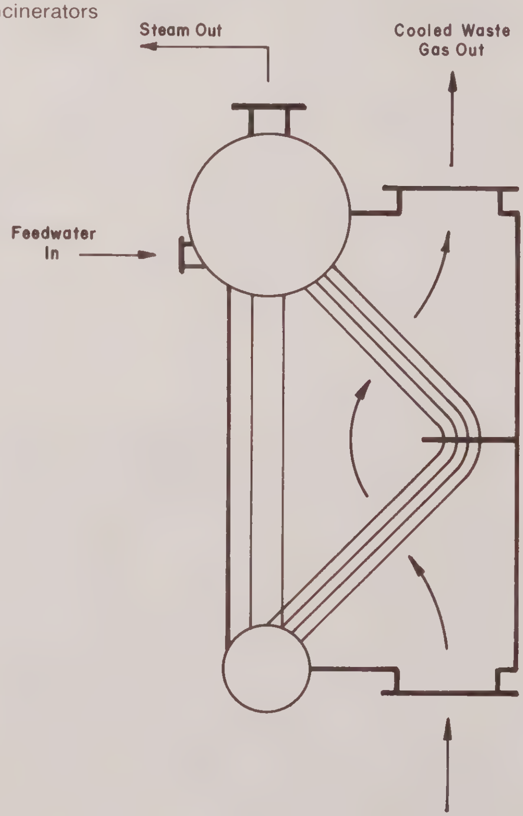
Typical applications include heating liquids with the heat contained in condensates from refrigeration and air conditioning systems; condensate from process steam; coolants from furnace doors, grates, and pipe supports; coolants from engines, air compressors, bearings, and lubricants; and the condensates from distillation processes.

3. Waste Heat Boilers

Waste heat boilers are ordinarily water tube boilers in which the hot exhaust gases from gas turbines, incinerators, etc., pass over a number of parallel tubes containing water. The water is vaporized in the tubes and collected in a steam drum from which it is drawn off for use as heating or process steam. The drawing indicates one arrangement that is used, where the exhaust gases pass over the water tubes twice before they are exhausted to the air. Because the exhaust gases are usually in the medium temperature range and in order to conserve space, a more compact boiler can be produced if the water tubes are finned in order to increase the effective heat transfer area on the gas side. The diagram shows a mud drum, a set of tubes over which the hot gases make a double pass, and a steam drum which collects the steam generated above the water surface.

The pressure at which the steam is generated and the rate of steam production depend on the temperature of the hot gases entering the boiler, the flow rate of the hot gases and the efficiency of the exchanger.

Waste wet boiler for heat recovery from gas turbines or incinerators



Should the waste heat in the exhaust gases be insufficient for generating the required amount of process steam, it is sometimes possible to add auxiliary burners which burn fuel in the waste heat boiler or to add an afterburner to the exhaust gas duct just ahead of the boiler.

Waste heat boilers are built in capacities from less than a thousand to almost a million cfm of exhaust gas and are typically used to recover energy from the exhausts of gas turbines, reciprocating engines, incinerators, and furnaces.

4. Gas and Vapor Expanders

Industrial steam and gas turbines are in an advanced state of development and readily available on a commercial basis. More recently special gas turbine designs for low pressure waste gases have become available; for example, a turbine is available for operation from the top gases of a blast furnace. In this case, as much as 20MW of power could be generated, representing a recovery of 20 to 30 percent of the available energy of the furnace exhaust gas stream. Maximum top pressures are of the order of 40 psig.

Perhaps of greater applicability are steam turbines used for producing mechanical work and for driving electrical generators. After removing the necessary energy for doing work, the steam turbine exhausts partially spent steam at a lower pressure than the inlet pressure. The energy in the turbine exhaust stream can then be used for process heat in the usual ways. Steam turbines are classified as back-pressure turbines, available with allowable exit pressure operation above 400 psig, or condensing turbines which operate below atmospheric exit pressures. The steam used for driving the turbines can be generated in direct fired or waste heat boilers. Among typical applications for gas and vapor expanders are:

- Electrical power generation and process steam.
- Compressor drives and process steam.
- Electric power generation and district steam heating.
- Fan drives and power generation.

The table on page 14 presents the collation of a number of significant attributes of the most common types of packaged industrial heat exchangers in matrix form. This matrix allows rapid comparisons to be made in selecting competing types of heat exchangers. The characteristics given in the table for each type of heat exchanger are: allowable temperature range, ability to transfer moisture, ability to withstand large temperature differentials, availability for retrofitting, and compactness and the allowable combinations of heat transfer fluids.

With regard to moisture recovery, it should be emphasized that many of the heat exchangers operating in the low temperature range may condense vapors from the cooled gas stream. Provisions must be made to remove those liquid condensates from the heat exhanger.

Liquid run-around system

One non-packaged system which is always custom designed to local conditions is the liquid run-around system. As shown in the diagram, the "run-around" involves two liquid-to-air exchangers, similar to the radiators on a car interconnected by two pipes. The circuit usually contains a glycol as a transfer medium kept flowing through the system by a pump. In this case, heat from exhaust air is being picked up by the glycol and transferred to the exchanger in the intake duct where it gives up its heat.

The run-around system requires piping and a constantly running pump and generally needs more attention than heat wheels, plate types or heat pipes. In addition, it can only transfer sensible heat and is generally less than 50% efficient.

However, if offers the great advantage of being usable where both the heat source and the heat requirement are physically separated from each other.

Many different applications are possible for the glycol run-around system capturing heat from both waste water or air streams. And the case history in this booklet describing an application at 3M of Canada in London, Ontario offers a particularly intriguing example of the results that can be generated with applied ingenuity using this system.

Heat reclaiming efficiency

Manufacturers often offer a single number to

express the efficiency of a typical heat recovery unit. However, in a given application, it is wise to remember that it is not always simple to calculate efficiency (particularly where latent and sensible heat transfer is involved) and that efficiency ratings for the same piece of equipment can vary up to 10 percent depending on relative temperature differences and volume flows.

The lesson? Heat recuperators have proven themselves efficient in industrial use, but the same savings will not result from two different applications, unless all conditions are exactly the same.

The heat pump

All of the four heat recovery systems discussed can be considered as straight "Btu exchangers" in that no matter what the efficiency of the unit, the temperature of the incoming fresh air or water will not quite reach the temperature of the

Operation and Application Characteristics of Industrial Heat Exchangers

SPECIFICATIONS FOR WASTE RECOVERY UNIT / COMMERCIAL HEAT TRANSFER EQUIPMENT	Low Temperature Sub-Zero – 250°F	Intermediate Temp. 250°F – 1200°F	High Temperature 1200°F – 2000°F	Recovers Moisture	Large Temperature Differentials Permitted	Packaged Units Available	Can Be Retrofit	No Cross-Contamination	Compact Size	Gas-to-Gas Heat Exchange	Gas-to-Liquid Heat Exchanger	Liquid-to-Liquid Heat Exchanger	Corrosive Gases Permitted with Special Construction
Radiation Recuperator			●		●	1	●	●		●			●
Convection Recuperator		●	●		●	●	●	●		●			●
Metallic Heat Wheel	●	●		2		●	●	3	●	●			●
Hygroscopic Heat Wheel	●			●		●	●	3	●	●			
Ceramic Heat Wheel		●	●		●	●	●		●	●			●
Passive Regenerator	●	●			●	●	●	●		●			●
Finned-Tube Heat Exchanger	●	●			●	●	●	●	●		●		4
Tube Shell-and-Tube Exchanger	●	●			●	●	●	●	●		●	●	
Waste Heat Boilers	●	●				●	●	●			●		4
Heat Pipes	●	●			5	●	●	●	●	●			●

1. Off-the-shelf items available in small capacities only.

2. Controversial subject. Some authorities claim moisture recovery. Do not advise depending on it.

3. With a purge section added, cross-contamination can be limited to less than 1% by mass.

4. Can be constructed of corrosion-resistant materials, but consider possible extensive damage to equipment caused by leaks or tube ruptures.

5. Allowable temperatures and temperature differential limited by the phase equilibrium properties of the internal fluid.

waste heat source.

One new development in heat recovery, the heat pump, has overcome this barrier by reclaiming Btu's and "stacking" them so that the reclaimed heat can be of a higher temperature than the waste medium — given an additional 40-50 percent contribution of electrical energy added to the exhaust heat.

Essentially, a heat pump works on a basic refrigeration cycle, in which an electrically driven compressor discharges hot, high pressure gas to a condenser where it becomes a liquid, giving up heat to the medium to be heated. As shown in the diagram, in the evaporator the liquid becomes a gas, absorbing heat from the exhaust air or waste medium.

With normal maximum exhaust temperatures of 115-130°F (work is underway on models with higher output temperatures), for every 1 Kwh put into the heat pump, 3 Kwh is received back in energy, giving a Coefficient of Performance (COP) of 3. Heat pumps are a significant development and will doubtless be a major part of the future of energy conservation.

As the temperature of the heat source drops, so does the COP of the heat pump. As a result, use is generally suggested only when the reclaimed temperature has to be higher than the waste heat temperature or possibly when supply and exhaust heat sources are in different locations and energy has to be added to the recuperated heat.

Creativity is the key

There are as many different processes as there are plants in Canada — and the opportunities for energy conservation measures are rife.

What is required is a creative approach — a willingness to break with past practice, without sacrificing practicality, for the sake of real dollar savings.

Two good examples of this type of thinking not mentioned in the case history section both deal in some way with cement. The first of these involves a new, more energy efficient "dry process" for making cement to be used by Inland Cement at a plant in Delta, B.C.

Under the conventional "wet process", raw materials are ground up and mixed with 32 to 39 percent water to form a slurry necessary for transport into the kiln. Here, the wet limestone and other ingredients can only receive the heat necessary to convert them into cement after the water has been driven off. The result is wasted energy and water — and a considerably larger kiln size requirement.

The new "dry process" eliminates water by using a preheat tower with four preheating stages — with heat supplied at each stage by exhaust from the cement kiln. Residual kiln exhaust will also be used to produce convection currents used to collect dust in roller mills on the site.

While it's a massive project, the company is convinced it will be profitable, given the energy intensiveness of an industry in which up to 3.5 million Btu's are consumed per ton of cement produced.

By coincidence, another recent process-related conservation development involved energy saving doors for plants that produced concrete blocks. Under the system manufactured in Canada by Phillipe Cousin Limited of Montreal, large kiln doors do not open wide to remove or insert racks while loading and unloading the kiln — losing up to 50 percent of the energy generated in the previous heating cycle.

With the new "pigeon hole" door plants, only one pallet at a time is inserted onto fixed racks inside the kiln. One small door is opened each time to inert "green" blocks and to remove the cured product.

Ideas like this are lurking behind process and combustion equipment in plants across Canada.

Air curtains replace exhausters on washer

The situation: A sheet metal parts washer using high pressure hot water/steam to degrease components at International Harvester's Chatham, Ontario plant used two 9,000-cfm exhausters to maintain a negative pressure inside the washer and prevent the escape of steam and water into the plant. Management realized that the 18,000 cfm exhaust, at temperatures between 95° and 110°F, represented a significant and avoidable heat loss.

Action taken: The exhausters were removed and air curtains installed to prevent steam escaping into the plant.

Energy/dollar savings: 3.8 MMMBtu @ $2.00 MMBtu = $7,600/year.

Cost of improvement: $4,000.

Recommendation: Consider eliminating exhausts from washers and other plant processes wherever possible.

Boiler combustion air preheated by flue gas recovery

The situation: At the Toronto bakery of George Weston Limited, 1,200 cfm of 420°F boiler exhaust was being vented to atmosphere, carrying with it considerable amounts of usable heat. A consultant was asked to explore possible heat recovery.

Action taken: A plate-type heat exchanger was installed to preheat boiler combustion make-up air.

Energy savings: Estimated at 1,450 Mcf/year. Savings would be greater if building operated year round. During summer months when heating loads are minimal, the boiler operated at only 1/3 to ½ capacity.

Dollar savings: 1,450 Mcf/year @ $2.00/Mcf = $2,900/year

Cost of improvement: $1,850.

Recommendation: Low cost options exist to recover heat from flue gases for various purposes within the plant. Explore them.

Coating oven heat recovery utilizes incinerator exhaust

The situation: Four of the large coating ovens at American Can of Canada Limited's Hamilton plant were used to bake a protective coating onto the interior of can cylinders and in the process produce volatile solvent vapours which environmental authorities insisted be removed through an incineration process. Management saw an obvious opportunity to capitalize on these clean 1200°F incinerator exhausts as a source of heat (previously supplied by natural gas) for re-injection into the coating ovens.

Action taken: A heat recovery system was installed on the coating ovens to allow controlled amounts of incinerator exhaust to be drawn down into the six zone control areas within the oven—and via a system of controls and dampers to maintain internal oven temperatures at desired levels up to 425°F.

Energy savings: (per oven).

Annual gas consumption without recovery = 43,176 Mcf/yr
Annual gas consumption with recovery = 26,124 Mcf/yr
Savings = 17,052 Mcf/yr

Dollar savings: (per oven)
17,052 Mcf @ $2.00/Mcf = $34,104/year.

Cost of improvement: $56,000 (heat recovery only).

Recommendation: Look to recovery systems to capitalize on incinerator flue gases. Bear in mind future technological developments when evaluating the economics of the investment required. American Can carried out these

improvements with the full knowledge that water based interior coatings (which would eliminate the need for incinerators and thus incinerator-produced heat) were in an early stage of development—along with a system of ultra-violet electric drying which was predicted to reduce energy requirements and size of the oven considerably.

Compressor cooling water for ammonia condensors and other uses

The situation: Labatt's Breweries realized that sending an average of 100 gpm (144,000 gals/day) of 80°F water down the drain represented a significant energy loss—particularly given their water requirement for ammonia condensors, boiler make-up water, and other uses.

Action taken: The company installed piping to take compressor cooling water to the boiler (40,000 gals/day) and the ammonia condensors (20,000 gals/day). City water previously used for both purposes averaged about 40°F. Compressor cooling water is about twice as hot and, therefore, requires less gas-fired heat to bring it to the required heat of 220°F.

Energy savings: Reductions in natural gas and water consumption total nearly $15,000/year.

Cost of improvement: $26,000.

Recommendations: Explore other uses than boiler feedwater for compressor and spot welder cooling waters or other clean water containing heat which would otherwise be wasted. For the 80,000 gals/day still being routed to drain, Labatt's hopes to find other uses including hose stations to wash floors, roof sprays to reduce heat load during the summer, and supply to a large storage tank, as a secondary water supply for fire control systems.

Cooling tower reduces refrigeration water consumption

The situation: Dough mixers at the Toronto plant of George Weston Limited have a requirement for cool water to chill the freon used in the refrigeration process. 17,000,000 gals/year were being used on a once through basis. A consultant advised the company of potential savings if this water could be recycled using a cooling tower.

Action taken: A cooling tower was installed which, because 60-65°F cooling water is required for plant refrigeration units, can be used for eight months of the year—with city water required for the remainder of the time.

Water savings: Estimated at 17,000,000 gals X 8/12 = 11,330,000 gals/yr.

Dollar savings: 11,330,000 gals @ $.6675/M gal. (plus sewer charge) = $8,600/year.

Cost of improvement: $12,500 with an annual operation cost of $1,500/year

Recommendation: Investigate the use of cooling towers to reduce cooling water demand from city sources. In some areas by-laws forbid once through water systems. This may be a trend to watch.

Ducting recovers exhaust for dryer preheating

The situation: Sangamo Limited's Toronto plant were forced to put in a new electrically-heated drying oven in the metal parts washing line. Rather than continuing to vent 3,000 cfm dryer exhaust to the atmosphere, it was decided to capture this 190°F air and utilize it to pre-dry metal parts in the drip section of the process.

Action taken: Using internal staff, 4 feet of ducting was installed to take the hot air from the dryer exhaust to the drip section and from there to atmosphere.

Energy savings: An estimated seven percent reduction in electric consumption due to lower drying times in the oven.

Dollar savings: estimated at $180/yr

Cost of improvement: $60.

Recommendation: Low cost alternatives to make use of waste heat from oven exhaust exist in many plants. As in this case, savings may be relatively small, but so are the investments required.

Economizer performs well at a glass plant

The situation: A glass plant, anticipating a possible fuel shortage, began exploring fuel conservation programmes.

Action taken: Effective heat transfer seemed to be an obvious need so their small packaged boiler was retrofitted with an economizer to heat boiler feedwater. The boiler was a two-pass gas-fired boiler of typical design, operating at 120 psig saturated (350°F) and producing both heat and process steam. It had 2,000 sq. ft. of heating surface an original rating of 200 hp. A custom-designed economizer was provided and installed. The manufacturer initially sized the unit to have an expected pickup of 640,000 Btu/hr. After a reasonable time in use, it was determined that the pickup averaged more than 1,000,000 Btu/hour.

Energy savings: Based on 5 days/week, 50 weeks/year, and 24 hours/day, a calculated 6 x 10^9 Btu/year are received by the economizer. Ignoring weekend savings, actual energy saved by the economizer (at 80% boiler efficiency) was 6,600 MMBtu in one year of operation . . . equivalent to 6,600 Mcf gas.

Dollars savings: At $2.00/Mcf for gas, savings amount to (6,600) ($2.00) = $13,200/year

Installation costs: Cost for second unit installation was $6,046 U.S. Thus the payback period was well under one year.

Recommendation: Many industrial applications offer opportunities for heat recovery — look into these options for your plant.

Economizer recovers waste heat for space heating in a dairy

The situation: A dairy was building a new warehouse and conventional gas heating was not available due to a gas shortage.

Action taken: It was decided to recover heat from boiler flue gases which were discharged to the atmosphere. The general design specifications were:

1. installation of a finned hot water coil in the stack breeching.
2. installation of a pump to circulate water to the fan coils in the warehouse.
3. a conventional hot water system to be used in the warehouse.
4. water from the finned coil to be automatically diverted to the new boiler feedwater preheater when warehouse heating requirements were satisfied.
5. provision to be made to automatically divert flue gases to the atmosphere when more heat was available than could be used.

Energy savings: The heat available from the flue gases, captured at 75% recovery, amounted to 4,875 MMBtu/year.

Dollar savings: At $2.00/Mcf, (4,875 Mcf) ($2.00) = $9,750/year.

Cost of improvement: The recovery system cost $17,340.

Recommendation: Look to heat recovery applications in your plant. While the primary need was heating the warehouse, additional benefits were derived by incorporating a feedwater preheater in the system. This made the total recovery system $9,040; more expensive than an electrical heating system, but the incremental cost was recovered in less than 2 years because of savings in operating cost. All stack recovery systems must ensure that gas temperatures remain high enough to avoid condensation and/or acid corrosion.

Filtration recovers waste solutions

The situation: At the Cambridge, Ontario plant of Butler Metal Products, the company operates a five-stage wash process for metal stampings. Every two weeks wash tanks are dumped so that the holding tank will not become contaminated. This effluent (which is 98% water with oil and drawing compounds) is removed by tank truck and incinerated at a cost of approximately $10,000 per year.

Action taken: The company is exploring the possibility of a continuous filtration system which will remove dirt and oil from the cleaning solution and reduce markedly the amount of solution carted away.

Energy savings: None directly; but the waste incineration is extremely energy intensive and

accounts for a large proportion of the costs associated with disposing of 2200 gal. of solution at two week intervals.

Dollar savings: Not available; however, it is assumed that the payback period will be less than two years.

Cost of improvement: $10,000 including hardware and installation.

Recommendation: Consider filtration systems or other means to prolong the life of process solutions and to reduce external haulage and/or incineration charges.

Floating ball blankets cuts heat loss on insulated tank

The situation: The management of Canadair Limited were concerned about surface heat loss from an otherwise well-insulated tank containing 64,000 lbs. of sodium dichromate at 200°F. Before taking action, controlled tests were carried out in which steam required to keep the tank up to temperature was metered with and without a ball blanket covering. Steam consumption in the latter case was cut by more than two-thirds.

Action taken: A layer of 2-inch diameter polypropylene balls was put in place on the tank surface, resulting in lower evaporation, greatly reduced heat loss and considerably shorter heat-up time after tank heating is shut off for weekends or holidays.

Energy savings:

Steam requirement without blanket = 1820 lbs/hr (533 Kw)

Steam requirement with blanket = 570 lbs/hr (167 Kw)

Reduction = 1250 lbs/hr = 6.9 gal/hr heating oil.

Dollar savings: 6.9 gal/hr × 24 hrs × 5 day/wk × 47 wk/yr = 38,916 gal/yr @ .35/gal = $13,620/year.

Water savings of approximately $100/yr were also experienced.

Flue gases recovered from ovens preheats air

The situation: At the Toronto bakery of George Weston Limited, consultants identified an opportunity for energy saving by capturing waste heat from flue gases from bread ovens for use in preheating oven air. Depending on conditions 200-500 cfm of flue gas at temperatures from 500-645°F were available from 2 gas-fired ovens using a total of five burners. Make up air was being ducted in from outside at an average temperature of 45°F.

Action taken: Five small plate-type heat exchangers were installed (one for each burner) using flue gases to preheat oven air to 370-470°F, depending on flue gas temperature.

Energy savings: Estimated at 2,650 Mcf/year

Dollar savings: 2,650 Mcf/year @ $2.00/Mcf = $5,300/year

Cost of improvement: $7,250.

Recommendation: Look for heat recovery applications where flue gases can be used to preheat oven or kiln make-up air.

A glycol run-around system recovers heat

The situation: 3M Canada Limited recognized the availability of large volumes of waste heat in the form of high temperature process exhaust and flash steam from high pressure condensate. The potential for heat recovery existed in preheating process oven entering air and in preheating building make-up air during the winter months; however, due to the large quantities of air involved, the distance between heat sources and heat users, and the availability of flash steam for heat recovery an air-to-air system was thought not to be suitable. Because of contaminants process exhaust air could not be recirculated.

Action taken: The company implemented a glycol run-around system which, although less efficient than an air-to-air system, had the advantage of lower initial cost and space requirements (no room existed for large duct runs) and the ability to recover heat from flash steam.

In the integrated system, three of the four heat transfer elements belong to a single processing unit. That is, heat is recovered from oven exhaust air and also from flash steam which is released from high pressure condensate from steam coils used to heat the oven entering air. This heat is

then transferred to the oven entering air before it enters the steam coils. The fourth heat transfer element—preheating of building make-up air operates only during the heating season although during that period it is the predominant heat user in the system.

Energy savings: the equivalent of 170,000 gal/yr of Bunker "C".

Dollar savings: 170,000 gal/yr @ $.35 gal = $59,500/yr.

Cost of improvement: $150,000.

Recommendation: Do not allow what appear to be physical barriers within the plant to stand in the way of heat recovery systems. 3M's experience with this particular system has shown that overheating of the building make-up air occurs in all but the coldest weather due to the quantity of heat available in the glycol. As a result, the company has subsequently installed a three-way valve and automatic temperature control at the make-up air glycol coils, to maintain make-up air at the desired temperature and to divert waste heat to the oven entering air where it can best be used.

Greater digester blow heat recovery saves oil

The situation: St. Anne-Nackawic Pulp and Paper Company had for some years operated a relatively small heat exchanger to recover heat from condensate from pulp digesters. Under the system condensate at 100 psig (laden with some cooking liquor and fibres) is vented to an accumulator tank at atmospheric pressure where it formed a considerable amount of flash steam which was utilized in a plate-type heat exchanger to heat river water from a low of 35°F (winter temperature) to 180-190°F for use in washing pulp for the bleach plant.

Given the increasing cost of fuel oil to generate steam and the amount of heat still being wasted due to the size limitations of the heat exchanger, it was realized that increased heat exchanger capacity would pay dividends.

Action taken: The company installed another plate-type heat exchanger 60 percent larger than the first one, and used both in parallel.

Energy savings: Steam reduction due to additional heat exchanger = 25 MMBtu/hour.

Dollar savings: 25 MMBtu/hr × 6000 hrs/yr × $2.00/MMBtu = $300,000/year.

Cost of improvement: $175,000 (Dcf rate of return—170%/year)

Recommendations: Many industrial processes offer opportunities for heat reclamation from spent liquids using a variety of heat exchangers. Look for potential applications.

Heat conserved from dryer exhaust

The situation: The outside air intake and exhaust stack for a high temperature drying system are located within 15 feet of each other on the roof of the 3M Canada plant in London, Ontario. For the energy conservation committee, it seemed an ideal situation for an air-to-air heat recovery system since only air was involved and the lengths of duct run were minimal. Available as a source of heat was 12,000 cfm of dryer exhaust which, depending on the process, ran about 200°F. Because of contaminants, the air could not be recycled.

Action taken: The company installed a bank of parallel plate heat exchangers to heat dryer make-up air (slightly less than 12,000 cfm since the dryer "runs negative") using the hot dryer exhaust. In winter, air from the heat exchanger averages 146°F while in the summer it approaches 200°F. In both cases it is further heated by steam to the 300+°F required dryer inlet temperature.

Energy savings: Reduction of steam heating requirements for dryer make-up air, taking into account the efficiency of the heating system and the efficiency of steam generation, saved the equivalent of 33,000 gal/yr of Bunker "C".

Dollar savings: 33,000 gal/yr @ $.35 gal = $11,550/year.

Cost of improvement: Not available; however, the project had a payback period of less than 2 years.

Recommendation: Explore direct recycling of dryer and other heated exhausts first, but where air contaminants and other factors prohibit direct recirculation, investigate the use of heat exchangers (the regenerative wheel, and heat pipe are two of the other types available) to capture waste heat from exhaust streams. The

parallel plate heat exchanger offers the advantage of being modular in construction and permits flexibility of building up, reducing, or re-using components of the heat recovery system elsewhere in the plant. Note that the efficiency of this type of heat exchanger increases with difference in temperature between intake and exhaust gases.

Heat-pipe regenerator preheats make-up air in rubber vulcanizing

The situation: Unable to obtain additional energy needed for expansion of vulcanization and other steam process facilities, a rubber company turned to heat recovery equipment as a means of saving enough energy to handle the proposed expansion.

Action taken:

1. A new thermal recovery unit was installed to replace the old steam-heated preheat coil.
2. A new 125-hp boiler was installed to provide higher pressure and additional steam to meet processing requirements.
3. Two old 30-hp vertical upright boilers were retired and the natural gas they used was applied to the new boiler.

The new thermal recovery unit was basically two heat exchangers connected with a series of heat pipes. Each heat pipe was a self-contained, closed system which transported heat from source to sink with very little temperature drop. Actual operation depended on vapour heat transfer and capillary action. Thermal energy transfer was very efficient since it was essentially an isothermal process.

Energy savings: The installation was completed in July 1973 and has operated trouble-free since then. The annual savings in energy are calculated to be 3,200 Mcf of natural gas (or 3.2 billion Btu). It should be noted that this case was a low temperature application, the exhaust air from which heat was recovered being at 94°F.

Dollar savings: At $2.00/Mcf, total savings are $6,400.

Cost of improvement: Costs are proprietary information. Critical point is that, in addition to monetary savings, the installation made heat recovered available to be used elsewhere, thereby allowing for the expansion.

Recommendation: Heat pipes are an attractive heat recovery option for many applications. See booklet text for a discussion of various heat recovery methods.

Heat recovered from boiler continuous blowdown

The situation: 3M Canada realized an opportunity to make full use of latent heat in boiler continuous blowdown water to heat both feedwater in the deaerator and boiler make-up.

Action taken: A system was devised in which 9.5 MM lbs/yr of boiler continuous blowdown water (drawn off just below water level on the steam drum) is passed into a flash tank. 1.6 MM lbs/yr of flash steam is separated from the water and used to heat the feedwater in the deaerator—supplemented by low pressure live steam. The remaining 8.7 MM lbs/yr of water leaving the flash tank passes through a float and thermostatic trap, and then through a shell-and-tube heat exchanger where heat is transferred into the boiler make-up water. Blowdown water is finally discharged to drain at relatively low temperatures (60-100°F).

Energy savings: On an annual basis, the system saves the company the equivalent of 19,000 gal/yr of Bunker "C" oil.

Dollar savings: 19,000 gal/yr @ $.35/gal = $6,650/year

Cost of improvement: Using all new equipment, $12,000. Because of the non-process related nature of the job, the Company was willing to accept the three year payback. (given energy prices at that time)

Recommendation: Investigate the use of boiler continuous blowdown water as an economical source of waste heat. The 3M system has proven to be relatively simple, reliable and maintenance free. Its critical point is the strainer on the blow down line ahead of the trap and heat exchanger. Due to the high concentration of suspended solids in the blowdown water, the strainer basket tends to plug quite rapidly and must be serviced frequently.

Heat recovered from textile waste water

The situation: Management of a textile mill

realized that there were major potential energy savings available from recovery of hot waste water from griege preparation ranges used for continuous fabric washing. Before energy conservation measures were implemented, 360 gpm of water at 160°F from the continuous washing operation was being discharged to a drain.

Action taken: The company installed a counterflow heat exchanger to preheat the 360 gpm of cold inlet water (yearly average temperature 63.3°F) using the wastewater as a source of heat. The heat exchanger was equipped with automatic back flushing to reduce the fouling problem characteristic of textile processes.

Energy savings: Based on a heat recovery factor of 58 percent and operation 4440 hr/yr: Savings = 360 gpm × 8.34 lb/gal × (160 — 63.3)°F × 60 min/hr × 4440 hr/yr × 1 Btu/lb°F × 0.58 = 45,000 MMBtu/yr.

Dollar savings: 45,000 Mcf @ $2.00 Mcf = $90,000/year.

Cost of Improvement: Assuming a five year capital recovery period, estimated annual amortization cost of the 10 MMBtu/hr heat exchanger plus the installation cost = $6,000/yr.

Recommendation: Evaluate the feasibility of heat recovery from all plant hot waste streams. Selection of proper counterflow heat exchange equipment for a particular system is important—recognizing the potential for excessive maintenance due to fouling problems.

Heat recovery saves energy in hydrocarbon incinerator

The situation: Solvent hydrocarbons from lithographic printing and subsequent baking of steel sheets for caps and closures at a can company posed potential air pollution problems. A third can line was to be installed and, while the two existing lines had fume incineration, there was no provision for heat recovery from the incineration. Primary specifications for the waste heat and incineration system included:

1. complete hydrocarbon destruction from baking
2. direct-flame incineration
3. operational economy

Action taken: Oven exhaust fumes were directed from the process gas forced-draft fan through the inside of the tubes of a recuperative type heat exchanger where they were preheated before entering the combustor. The exchanger was a two-pass cross-counterflow system with gases entering at up to 324°F and leaving at up to 927°F to enter the combustor. Incinerated hot gases (at 1400°F) leave the direct-flame combustor, pass over the outside of the heat exchanger tubes, and exit to the stack as cleaned, cooled gases at about 836°F.

Energy savings: Based on a process flow rate of 8,500 cfm and 6,000 hours/year of operation, the savings in gas consumption amounted to 54%.

Dollar savings: at a cost of $2.00/Mcf, savings amounted to $80,000 per year.

Cost of improvement: The total cost of the incineration-heat recovery system, including installation and research work, was $100,000.

Recommendation: Consider recuperation for oven exhaust fumes.

Heat recovery saves energy, water in sterilizing retorts

The situation: At the Leamington, Ontario plant of H. J. Heinz Limited, large retorts are filled with jars of products to be sterilized. Since cold water can not be added to the retorts without thermoshock, 2280 gallons per cycle of city water first had to be heated from its average 50° temprature to 170°F before being added to the retorts. Addition of steam then brought the water temperature to 240°F whereupon hot water was gradually removed and sent to drain and cold water gradually added in a cooling cycle which reduced water temperature in the retorts to 90-100°F.

Management was aware that large amounts of hot water removed during the cooling cycle were being wasted, with a consequent excessive consumption of steam to heat cold city water for the next retort sterilizing cycle.

Action taken: The company installed a 6,000 gallon tank complete with automatic timers, air

operated valves and made necessary tie-ins to the reclaim line from each retort, so that hot water could be recovered from the retort during the cooling cycle and used for the next heating cycle.

Energy savings: Assuming that 60 percent of the 2,280 gal/retort cycle will not have to be reheated (i.e. 40 percent make-up), 2,280 × .60 = 1,368 gal/cycle (approx.).
Steam savings =

$$\frac{120°F \times 1{,}370 \text{ gal} \times 8.33/\text{gal}}{1{,}000 \text{ Btu/lb}} =$$

1,368 lbs/cycle.

Dollar savings: @ \$2.50/M lbs. steam = \$3.42 cycle × 4,200 cycles/yr = \$14,364/year.

Cost of improvement: \$28,500. This yielded a dcf rate of return on investment of 42% and a payback period of under 2 years.

Recommendation: Clean hot water flushed to drain always represents a major loss of heat which could be utilized in the plant. Look at every possible use for hot water before allowing it to carry Btu's to the sewer.

Heat wheel reduces energy costs in a paint shop

The situation: State law required a complete air change in a paint shop at 2-minute intervals. At the same time, air movement at the paint spray station had to have a minimum velocity of 120 ft./min./sq. ft. of booth opening. Also, maintenance of a 75°F temperature in the paint shop during the winter was desired. It was determined that 90% of the wasted sensible heat in the exhausted air could be recovered and used to preheat incoming air for the paint shop.

Action taken: Exhaust air was collected into a common duct system—the sources were paint spray booths, fume incinerators on bake ovens, a washer vent, and a drying oven. The final design was an energy recovery package mounted on the plant roof with an 8-ft. diameter heat wheel as the heart of the system. The wheel was rotated by a small electric motor. Blended exhaust air entered at 225°F through one side of the wheel and outside air at ambient temperature passed through the other side. The sensible heat exchanged was used to provide the 75°F primary heating requirement. Exhaust air in excess of that needed for the heat exchange was by-passed around the wheel. Three standard cycles are possible: the energy recovery cycle, the recirculation cycle, and the ventilation cycle.

Energy savings: The ventilation requirements had to be met; if they had been met without the heat recovery system, an additional 55,380 gals. (U.S.) of propane per year would have been required.

Dollar savings: At \$.42/U.S. gal., (55,380) (\$.42) = \$23,260/year.

Cost of improvement: Not available.

Recommendation: Look to heat wheels or other heat exchangers to recover waste heat from plant exhausts.

Low temperature chemicals reduce spray wash energy consumption

The situation: Spray wash operations for metal parts at the Toronto plant of Carrier Air Conditioning (Canada) Ltd. operated at temperatures approaching 160°F—meeting the requirements for detergents and chemicals used in the five-stage system (two water rinse stages). It was proposed that low temperature chemicals could be purchased at the same low cost and allow substantial savings in gas-fired heating for water for the system.

Action taken: Stages 1 and 3 of the process (detergent wash and conversion coating) were converted to low temperature products usable in water temperatures averaging 110°F. Stage 2 (water rinse) could then be lowered to the same operating temperature.

Energy saving: Using the formula: Pump capacity (gpm) × 60 min/hr × 8.34 lb/gal × degree drop = Btu/hr savings.
For each stage affected, it was determined that total hourly energy savings = 2,390,010 Btu/hr.

Dollar savings: Based on 24 weeks per year operation and reduced consumption of natural gas in the boiler = \$4,589.

Cost of improvement: Nil. Cold water chemicals cost slightly less than those formerly used.

Recommendation: Explore the use of low temperature chemicals and detergents for spray, immersion and coil coating applications of metal parts. In addition to savings in gas consumption, reduced temperature operations offer lower water consumption (less evaporation at lower temperatures), electrical savings (reduction in exhaust fan capacity), reduced maintenance on heating coils, space savings (frequently one boiler and associated fuel storage can be eliminated), and greater safety to workers not exposed to the chance of burns from hot solutions.

Process water heated with flue gas heat

The situation: A candy manufacturer recognized the potential for energy savings by using 15,000 lb/hr at 600°F from two oil-fired boilers to add heat to process water currently heated by an oil-fired system.

Action taken: A waste heat recovery system was installed in the stack of the two boilers (each rated at 7500 lb/hr exhaust) to cool flue gas steams to 300°F and to add this heat to process water from the water heater.

Energy saved: Recoverable energy through the waste heat system was: 15,000 lb/hr × 0.26 Btu/lb °F × (600-300) °F = 1.17 MMBtu/hr.

An equivalent amount of energy was saved in the operation of the hot water heater = (50 gpm from 50°F to 180°F).

As a result of the heat recovery installation, outlet temperatures from the water heater were reduced to 133°F with the extra 47°F added through the 1.17 MMBtu/hr recovered from boiler exhausts.

Dollar savings: Operating 6000 hr/yr:
1.17 MMBtu/hr × 6,000 hr/yr × $2.00 MBtu (approx.) = $14,000/yr.

Recommendation: Pursue the possibility of using waste flue gas heat as a method of producing hot water. In order to avoid corrosion problems, exhaust should not be cooled before 300°F and water entering the heat exchanger should have a minimum temperature of 125°F.

Radiation recuperator heats building air in automatic transmission plant

The situation: Tests were conducted on two identical bent-tube batch furnaces in an automatic transmission plant. One furnace remained standard and the other was equipped with recuperators.

Action taken: The recuperators were of standard design and operated to extract energy from hot flue gases and transfer this recovered energy to incoming cold air. Both furnaces were equipped with gas meters to measure total volume and rates of gas consumption.

Test particulars include:
–2.0-2.5% Oxygen in exhausts (10% excess air);
–Set point temperature, 1525°F.
–Load approximately 500 lbs.
–Heating cycle (set point temp. recovery).
–33 mins. for standard furnace.
–34 mins. for recuperator furnace.
–Soaking time.
–59 mins. for standard furnace.
–58 mins. for recuperator furnace.

Energy saved: Operating with pilots, 6 days/week, twelve 1½ hr. cycles per day, and all other times at idle, the gas consumed by the standard batch furnace is 4.5 MMcf/yr. Recuperation saves 860 Mcf per year, or 19% fuel, in one year. Without pilots, the recuperated furnace saves about 914 Mcf/year.

Dollar savings: (860 Mcf) ($2.00/Mcf) = $1,720/year.

Cost of improvement: A new furnace installation, where recuperators could be installed as the furnace is built, cost $4,950 for the recuperators in the U.S.

Recommendation: Look to recuperators or other heat exchangers to preheat building make-up air.

Rinse tank controllers, aeration save water

The situation: Engineers in one of Sangamo Limited's plants realized that considerable

amounts of water were being wasted by uncontrolled supply to rinse tanks in the plating operation.

Action taken: The company decided on a two-pronged program of rinse tank controllers and aeration to cut down on water consumption yet prevent excessive contamination in the tanks. As part of the system, conducting sensors, preset for allowable level of contamination in the tanks, are attached to a master solenoid control. As water is drawn into the tank, air is automatically provided into the tank through perforated PVC water lines — assuring that contamination is evenly distributed through the tank and that the sensors are not "fooled" by local concentrations of contaminants.

Water savings: 24,600,000 gal/yr.

Dollar savings: 24,600,000 gal/yr @ 6.91 cents per 100 gal. = $17,000/yr.

Cost of improvement: $3,600 materials + $900 labour = $4,500.

Recommendation: Continual supply of water to rinse tanks incurs unnecessarily high water bills. Automated systems offer a low-cost option to reduce water consumption and generate an attractive return on investment.

Tank cover modifications promote use, energy savings

The situation: Canadair Limited, Montreal had built two insulated steel covers for a pair of 95 sq. ft. salt baths heated constantly to 920°F. The covers were designed to cut down on the considerable surface loss of heat and water to the plant air but due to their weight, sectional nature and inability to be lifted by crane, were not being put in place by employees when tanks were not in use. (Due to infrequent use of the baths, full covers were preferable to a ball blanket covering.)

Action taken: A steel frame for the covers was designed and built with hooks which allowed it to be picked up in one piece and put in place using a crane. The covers are now in place whenever the tanks are not in use.

Energy savings: Based on a mean usage of the covers 18 hrs/day every day of the year:
Previous heat loss = 421,325 Btu/hr (123 Kw)

Present heat loss = 126,398 Btu/hr (37 Kw)

Reduction = 294,927 Btu/hr (86 Kw)
Additional small savings on water consumption were also attained.

Dollars savings: 294,927 Btu/hr × 18 × 365 = 1.94 MMMBtu/yr × 3,412 Btu/Kwh. 556,700 Kwh/yr @ $.025/Kwh = $13,917/year

Recommendation: for those applications where heated tanks are open infrequently consider the use of a lid rather than a floating ball blanket. At Canadair a lid reduced heat loss by 70 per cent. Reduced power for tank heating proved to be the largest single contributor to reducing the plant's peak electrical demand.

Twin insulation conserves plating tank heat

The situation: Heated plating tanks (165°F) in the Toronto plant of Sangamo Limited were not insulated against surface heat loss or loss of heat energy through the walls and bottom of the tanks. An energy-conscious conservation committee realized the opportunity to insulate the tanks to save energy and at the same time improve air quality in the plating department through reduction of evaporation.

Action taken: Following an experimental program on one tank in which they metered electrical consumption before and after insulation, the company embarked on a program to insulate all 19 of the plant's tanks. One inch urethane foam was applied to the exterior of the tanks and clad in an outer sheet of .030 inch aluminum. A layer of ½-inch polypropylene balls was added to cover more than 90 percent of the surface area of each tank.

Energy savings: Eliminated 50% of measured 35,520 Kwh/yr loss (per tank) = 17,260 Kwh/yr.

Dollar savings: 17,260 Kwh @ $.025/Kwh = $431/year.

Cost of improvement: $280 per tank.

Reccmmendation: Look to tank insulation and plastic balls or other inert floating material to cut down on overall tank heating losses. Applicable in a wide variety of processes, the plastic balls are available in a range of sizes (10mm to 100mm diameter) and materials (polypropylene and high and low density polyethylene) to match

particular process requirements.

Vapour loss reduced with polystyrene chips

The situation: A small chrome plating operation realized that it had a heat loss problem due to evaporation from its four open-top 18 sq. ft. tanks. Three of the tanks contained either copper, nickel or chromium solutions. The fourth was used for water rinse. All were heated four days/wk. 8 hr/day using electrical immersion heaters (total capacity 36 Kw) to temperatures ranging from 100°F to 150°F. Evaporation heat loss was increased by agitation in one of the tanks during plating operations and by forced ventilation in the overall area.

Action taken: Plant engineers covered the exposed liquid surface of the plating tanks with (2 inch x 2 inch) expanded polystyrene chips.

Energy savings: Heat loss was reduced from about 450 watts/sq. ft. to about 35 watts/sq. ft. Annual savings: 72 sq. ft. × (450-35) W/sq. ft. × 1 kw/1000W × 32 hr/wk × 50 wk/yr = 48,000 Kwh/yr.

Dollar savings: 48,000 Kwh/yr × $.025 KWh = $1,200/yr.

Cost of improvement: $450.00.

Recommendation: Consider the possibility of reducing evaporation losses from any heated, open top vessel by covering the surface of the liquid with floating inert material. Many types of foam material and hollow beads or balls are available, in a variety of plastic materials, depending on the temperature and chemical make-up of the liquid.

Waste heat is recovered from refinery stack gases

The situation: At the Sun Oil refinery in Sarnia, Ontario, the company had as its objective recovery of heat from flue gases being vented to atmosphere at temperatures for 750-850°F. Each heater or boiler had its own stack.

Action taken: A common duct work was used to combine the different flue gas outlets—with the combined flue gas stream sent to an economizer (heat exchanger) where heat was recovered by transferring it to boiler feed water to generate steam. The economizer flue gas was discharged to the atmosphere through a new stack.

The duct work and economizer were designed for a minimum friction drop compatible with the draft produced by the stack. Instrumentation and flue gas analyzers were provided at each heater and boiler outlet, to allow for proper combination control.

Economizer feedwater at 58,600 lb/hr is preheated to 200° to minimize the temperature difference between the water and flue gas. This results in a reduction of the heat transfer area for a given heat transfer rate. A direct duct around the economizer to the stack is provided to allow for economizer maintenance.

Energy saved: Combined flue gas temperature entering the economizer is 750°F with an outlet temperature of 520°F. The heat recovered is calculated at 20 MMBtu/hr.

20 MMBtu/hr × 24 × 365 = 175,200 MMBtu/yr; Bunker "C" fuel = 185,000 Btu/Imp. Gal.

Dollar savings: 20 MMBtu/hr = 950,000 gal/yr @ ¢.35/imp. gal. Bunker "C" = $332,500/year.

Cost of improvement: $210,000.

Recommendation: Look to flue gases as a ready source of waste heat. Installations do not have to be of this size to be both practical and economical.

Waste heat recovered from pollution control equipment

The situation: Management of a metal finishing plant had added an incineration unit to a large paint curing oven in order to discharge only clean air to the atmosphere. Upon examination, it was decided that substantial energy savings could be made by recovering heat from incinerator flue gases. The incinerator was designed to accept up to 28,000 cfm of 700°F exhaust gas from the finishing oven—increasing the heat of this gas in the incinerator to 1400°F by natural gas and the heat of combustion of the solvent vapour.

Action taken: Instead of exhausting hot clean air from the incinerator, exhaust is now passed to a heat exchanger to raise the temperature of oven

exhaust before it enters the incinerator—reducing the amount of natural gas needed for incineration. On leaving the heat exchanger, the clean exhaust air is sent to a waste heat boiler, producing 50 psi steam for general plant use. The total energy utilized is about 50 per cent of that generated by the incinerator (40 per cent in the heat exchanger and 10 per cent in the boiler).

Energy savings: Assuming operation of the incinerator at 75% of design capacity: Energy produced = 28,000 cfm × 0.0807 lb/cf × 60 min/hr. × (1400-700)°F × .28 Btu/lb °F × .75 = 20 MMBtu/hr.

At 50% utilization of this waste heat: Annual energy saving = 20 MMBtu/yr × 6000 hr/yr × .50 = 60,000 MMBtu/yr.

Dollar savings: 60,000 MMBtu/yr = 60 MMcf/yr @ $2.00 Mcf = $120,000/year

Cost of improvement: Not available

Recommendation: Clean air requirements may make more widespread the installation of equipment to recover or destroy solvent vapours from finishing ovens and spray booths. If incineration is used for this purpose in your plant, consider methods to recover waste heat from the operation.

Tips for saving money through process design and heat recovery

Process design

1. Schedule baking times of small and large components to minimize use of energy.
2. Use vapor recompression design in distillation processes.
3. Use "side draw" principle in distillation column design.
4. Use continuous equipment which retains process heating conveyors within the heated chamber.
5. Use direct flame impingement or infrared processing for chamber type heating.
6. Convert from indirect to direct firing.
7. Convert from batch to continuous operation.
8. Use shaft type furnaces for preheating incoming material.
9. Convert liquid heaters from underfiring to immersion or submersion heating.
10. Minimize unessential material in heat treatment processes.
11. Change product design to reduce processing energy requirements.
12. Reduce scrap production.
13. Upgrade obsolete or little used equipment.
14. Reduce process temperatures to the lowest level consistent with product quality.
15. Conserve hot water that would otherwise be flushed to sewer (e.g. compressor cooling water).
16. Utilize floating balls or chips to minimize heat loss on open process tanks.
17. Insulate process tanks.
18. Use rinse tank controllers to minimize water consumption.

Heat Recovery

1. Use the overhead condenser to generate steam from condensates in a distillation process.
2. Use hot flue gases in radiant heater for space heating ovens, dryers, etc.
3. Use heat in flue gases to preheat products or material going into ovens, dryers, etc.
4. Use hot process fluids to preheat incoming process fluids.
5. Use hot flue gases to preheat wastes for incinerator boiler.
6. Use "waste" heat from hot flue gases to generate steam for processes or consider selling excess steam.
7. Use "waste" heat from hot flue gases to heat space conditioning air.
8. Use "waste" heat from hot flue gases to preheat combustion air.
9. Use engine exhaust heat to make steam.
10. Recover fuel value in polluted exhaust air.
11. Recover fuel value in waste by-products.
12. Use flue gases to heat process or service water.
13. Use oven exhaust for space heating.
14. Use recovered heat from lighting fixtures for useful purpose; i.e., to operate absorption cooling equipment.
15. Use flue gas heat to preheat boiler feedwater.
16. Recover "waste" solutions through filtration or treatment.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1^\circ = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY THROUGH PRODUCTION OPTIMIZATION

4

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SAVING MONEY THROUGH PRODUCTION OPTIMIZATION 4

Saving money through Production Optimization

Introduction:

Production optimization is perhaps the most wide ranging in scope of all the subject areas covered by the series on energy conservation. Involving the entire materials management function, it is the area which appears to have been least exploited by Canadian industry.

Not surprisingly, it is an area which offers a major potential for reductions in energy consumption — depending on the relationship in a particular industry between use and incremental production.

This booklet attempts to deal with some of the broader issues and to offer some concrete examples of suitable programs carried out by Canadian and American companies.

Production Optimization

Of all the energy conservation measures that can be implemented in Canadian plants, none are as conceptually simple as those whose purpose is to improve production at present rates of energy consumption or reduce energy consumption while maintaining present output.

However, more than any of the other area of potential dollar savings, it requires a full and objective perspective on the entire "materials management" function within the plant. The flow of materials through a plant to market is a continuous system and any change that is made along the line has direct repercussions for all activities that follow it in sequence. As a result, the question of energy and production optimization must be viewed as an integrated entity in which both equipment, materials and people are important variables.

The premise that a given amount of product must be produced in a given period (a work week) using a given amount of raw materials and a fixed labour component, provides major constraints; but since equipment and manpower are rarely employed flat out 24 hours a day, over a 7 day week, a large number of options remain for scheduling operations in a way that minimizes energy consumption.

Similarly, in many cases equipment can be modified so that it makes more efficient use of the same source of energy — or uses a different, more economical form of energy.

A final major area for potential saving does not actually result from reduced consumption. Here, unique scheduling opportunities exist because of the nature of electrical energy and the way in which utilities bill for its use. Even consuming the same number of kilowatt hours every week, very substantial savings are offered if "power factors" or "load factors" can be carefully controlled.

Energy reduction through scheduling.

Scheduling control then, has two components. It can be used to actually minimize consumption on a per unit basis, or it can be employed so that financial penalties are not incurred on electric power bills. The degree of complexity entailed in achieving each objective will depend on the nature of the plant and the process.

For example, it is relatively simple to defer the charging of lift truck batteries to another shift or an off-shift period to reduce peak electrical demand. Since virtually no manpower is required, there are no complications with shift premiums or of other labour factors.

In the same way (see case history), it is often straightforward to eliminate downtime between shifts or to turn off equipment during offshift periods. It is, however, substantially more complex to reschedule operations so that equipment and energy utilization are scheduled over, say, a two-day continuous period rather than over a five-day period of low utilization.

The "trade-offs" involved are often numerous and must be considered in the decision-making process; however, after examination, rescheduling often involves an investment of little more than temporary inconvenience in the overall production process. Both employees and

management can learn to live with new ways of doing things. Savings involved can be quite substantial, and they make a direct contribution to company earnings.

Many of these ideas can be expected to follow an analysis of the plant's energy usage through an audit (see Booklet I in this series)—an essential first step. However, a critical catalyst in the process is an active, inquisitive "way of thinking" that begins to see production as an opportunity to improve production rates *and* energy efficiency.

Today's energy costs make it imperative that companies become conscious of their products on an energy cost per unit basis. It stands to reason, then, that both factors: production rates and energy consumption, must be taken into account.

Scheduling to reduce billing.

Any scheduling or production changes made which increase energy efficiency will ultimately see a reduction in the amount of energy consumed. If, as in one of our case history examples, cam controllers reduce the requirement for compressed air on a machine—deferring or eliminating the need for a new compressor—energy which was used to create the compressed air will obviously be reduced.

If a plating line can be put to three days of intense use and gas-fired heat on the baths reduced or eliminated for the other four days of the week, the reduction in gas consumption will be reflected directly on the bill. The same principle applies to oil-fired applications where straight consumption is really the only factor involved in establishing billing.

The situation with electric power, however, is more complex and offers opportunities for monthly savings despite the fact that actual consumption in kilowatt hours may not have decreased at all.

And while electric power bills are relatively complex documents, and methods of billing vary from area to area, in general, the main components upon which electrical bills are based remain the same. Normally, the bill is comprised of charges for:

- total energy consumed during the month
- the peak demand for the month (total load taken for a specified duration during the month)
- less any applicable discounts for conditions of supply (transformer allowance)

Consumption in kilowatt hours offers the greatest potential for savings through any number of energy conservation programs in which the actual usage of electrical power is reduced on an aggregate basis over the billing period. Consumption can be wasted by leaving things running when not needed, through undersized feeder lines, lack of insulation, oversized motors, excessive lighting, overloaded transformers or simply by a poor choice or utilization of equipment or processes. Throughout this series of booklets, there are many examples of how electric power consumption can be reduced.

However, the "demand" for power is also included on the bill. For example, even if the maximum or peak power demand for a plant only occurs for a 20-minute period during the billing month, the utility must charge to cover the capital investment in equipment necessary to meet the peak requirement.

Peak demand, along with consumption, is normally itemized on an electric bill.

And, if examined, the bill will give the energy consumption in kilowatt hours, demand in kilowatts and the charge for each value. However, it is unlikely that the bill will give any indication of either demand efficiency ("power factor") or of demand scheduling ("load factor")—both critical considerations in designing systems to reduce billing charges.

Happily, however, load factor can be determined using elements of the power bill and for companies with two electrical meters, power factor can be easily determined.

Power factor.

In simple terms, local electrical utilities will generally allow most companies a minimum level of 90 percent efficiency in their peak power demand. Below that level a financial penalty is charged.

Usually, there are two demand meters in the plant, one metering incoming power demand (in Kilovolt amps or KVA) and the other metering

TYPICAL EFFECTS OF UNDERVOLTAGE ON UTILIZATION EQUIPMENT

Induction motors. 10% undervoltage decreases starting and maximum running torque 19%: decreases full load speed 1½%; increases full load current 11%; and causes a slight rise in operating temperature.

Incandescent lamps. 10% undervoltage reduces light output 30%; 20% undervoltage reduces light output over 50%.

Fluorescent lamps. 10% undervoltage cuts light output about 10%. Low voltage often results in unsatisfactory starting.

HID lamps. 10% undervoltage reduces mercury vapor light output 15% to 25%; other types 5% to 15%, depending on ballast type and there may be a color shift. Lamps go out at 15% to 20% undervoltage.

Resistance heaters. 10% undervoltage produces a 19% decrease in heat output.

Infrared heating. Radiant energy is proportional to temperature. Undervoltage lengthens processing time, decreases production.

Electronic equipment. Undervoltage drastically reduces tube life and can destroy gas-filled tubes in minutes.

Capacitors. The corrective capacity of capacitors varies with the square of the voltage. 10% undervoltage reduces corrective capacity 19%.

used power demand (in Kilowatts). In a typical plant, for example, the KVA meter may register 1,000 KVA and the Kw meter 700 Kw.

As a result, the utility would bill the plant for 90 percent of the KVA reading or 100 percent of the Kw, whichever is greater. Thus, the billing in this case would be for 900 Kw rather than the 700 Kw actually used.

If, however, the power factor was corrected from its present $\frac{700}{1000} = 70$ percent to an acceptable 90 percent, input demand would fall to $\frac{700}{.9} = 778$ KVA and the demand bill would now be for 700 Kw—and there would be no power factor penalty. (See case history "Synchronous motor improves power factor").

Causes of low power factor.

Before measures can be implemented to improve low or "lagging" power factor, it is essential to understand its cause. Simply stated, that cause is "inductive load" caused by use of electromagnetic devices such as:

- induction motors
- non-power factor corrected fluorescent and high intensity lighting fixture ballasts
- arc welders
- solenoids
- induction heating equipment, lifting magnets and many other inductive devices

However, the most notorious offenders are the induction motors. These have a poor power factor at best—and one that becomes even worse under conditions of light loading.

In one plant, for example, it was found that there were over 100 inductive motors idling overnight between shifts. In most plants it is also easy to find a surprising number of 20 hp induction motors driving 5 hp loads. And the penalty incurred by these practices is high. Most significant, of course, is the heavy billing penalty; but, in addition, low power factor can result in higher currents than necessary—causing excessive voltage drop and system losses in the plant. In many parts of Canada this, in itself, has resulted in thousands of dollars in unnecessary installation of new substations or re-wiring.

To reduce penalties caused by power factor, the most economical solution is to install a bank of capacitors at the main sub-station or plant electrical input. In many cases it may be more advantageous to install the capacitors at the offending piece of equipment. Where new motors are being purchased, synchronous machines providing "leading" current, are an alternative to capacitors. The advice of a utility, contractor or electrical consultant can be useful here.

Load factor correction.

Another factor which should be considered in electrical billing reduction is "load factor" or the

HOW A PEAK DEMAND CONTROLLER SAVES MONEY

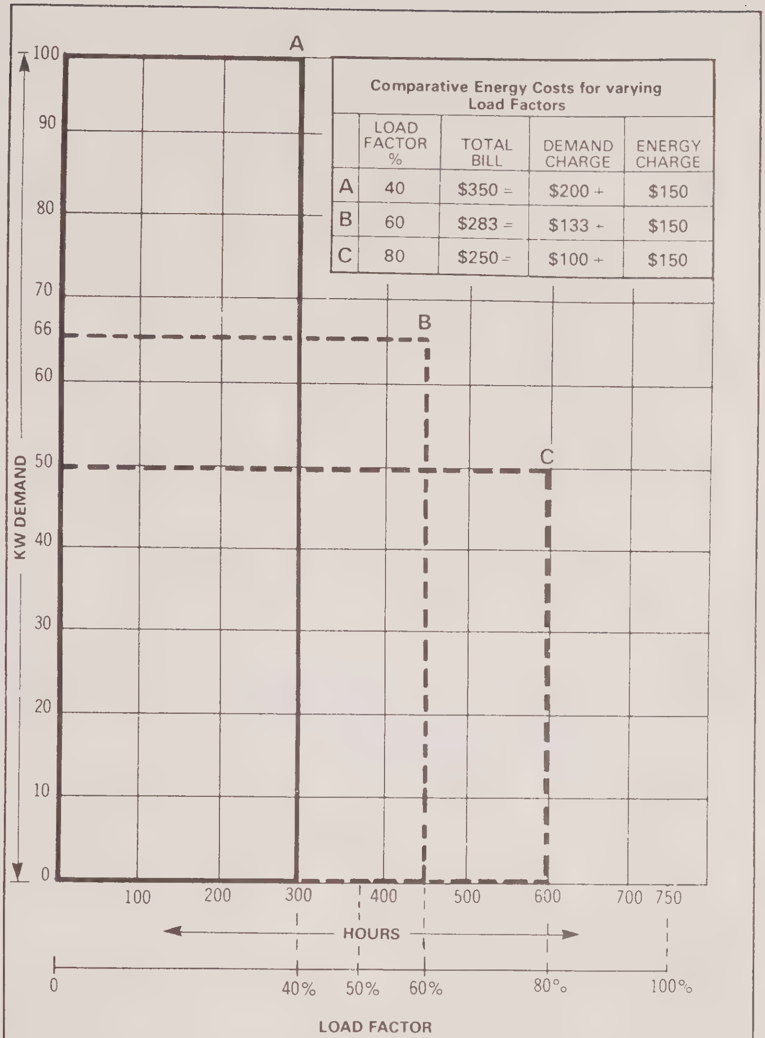
Electrical Utilities bill commercial and industrial customers on a combined "demand" and "energy" rate structure.

The demand portion is indicated by a peak reading meter which shows the maximum kilowatt (kw) load connected for a ten or fifteen minute minimum period during the month. This charge is designed to cover the capital equipment costs of power generation, while the kilowatt-hour (kwh) charge for energy pays for fuelling and maintenance costs.

The chart shows how this demand charge affects a typical bill. Notice that the amount of energy used (and thus the energy charge) is constant. It is obvious that block C is a much more efficient user of electrical energy and generation capacity than block A—therefore the total cost is less.

The measure of efficiency is called "load factor". (100% efficiency would require continuous use of a given amount of load for every hour of the month.)

The purpose of the peak demand controllers is to lower the demand (and hence increase the load factor) by controlling some secondary loads. The chart at the top of the next page shows what happens to a typical load curve of an all-electric building. (The block representation has been continued for clarity.) By "moving" the peak over or spreading it out in time, (controlled load line), the control often pays for itself in savings within two years!



Comparative Energy Costs for varying Load Factors

	LOAD FACTOR %	TOTAL BILL	DEMAND CHARGE	ENERGY CHARGE
A	40	$350 =	$200 +	$150
B	60	$283 =	$133 +	$150
C	80	$250 =	$100 +	$150

Chart based on $2 per kW Demand and 0.5c per kWh energy

ratio of average demand to peak demand. Easily calculated, by dividing the total demand in kilowatt hours by the peak demand, multiplied by the number of hours in the month (730), the load factor actually determines the plant's cost of energy per kilowatt hour.

In the case of a plant, say with a consumption of 86,000 Kwh and a peak demand of 560 Kw, load factor is:

$$\frac{86,000}{730 \times 560} = .21 \text{ or } 21\%,$$

which is slightly below the average figure of about 25% for a plant operating on a single 8-hour shift, 5 days per week. For a double shift, the average load factor is approximately 40%. Assuming for the sake of the bill that the demand charge is $2.00 per Kw, the demand section of the bill will total 560 X $2.00 or $1,120 for a total of $4,030. The energy charge will be 86,000 Kwh X 1.5 cents per Kwh or $12,290. As in most cases, demand charge amounts to nearly 50% of the total bill. Its an area where substantial cost savings are available.

Under the example above, the average cost per Kwh is 2.8 cents. But if the plant could reschedule power demand by running some machine on an evening shift, increasing the load factor to 40%, the average cost per Kwh would be reduced to 2.19 cents per Kwh—and demand

OTHER APPLICATIONS OF A PEAK DEMAND CONTROLLER

Emergency Generator Control.

Reducing switchgear capacity (this alone can save $20. per Kw in larger installations).

DOESN'T THE CONTROL AFFECT NORMAL OPERATION?

In most cases — no. If the control is designed and set properly for the installation, there should be little or no noticeable effect on user convenience. Proper control application does rely on the thermal storage capacity of the controlled loads however, and a qualified representative should be contacted regarding details concerning specific loads.

HOW DOES A PDC WORK?

The PDC monitors power coming into the building in the same way in which the utility does. The middle chart shows basic control operations as the demand increases — load is removed, as demand decreases load is added. The graph at the bottom shows how the control continuously removes or adds load in order to maintain the maximum demand setting. The total load drops when the controlled loads are satisfied.

Notice that the control has a fixed priority sequence — load #1 is most important, while load #6 is least important and therefore off longer.

CAN ZONE HEATING BE CONTROLLED?

Yes, using available load cycler options.

The cycler restores equal priority to all zones which are connected to it — thus, zone #6 could get as much energy as zone #3 or zone #1 if all 6 steps were cycled.

The maximum demand setting regulates the total number of zones on at any given time to share all available power.

(This is what is called "forced diversity" operation — the thermostats on individual heaters are forced to operate during controlled periods to ensure minimum demand.

Remember that this can be done because of the building (or load) thermal storage capacity — and the fact that even a non-controlled load which is causing the peak contributes to the total building heat!)

HOW IS THE CONTROL SET?

The control may be set either manually or automatically. Several types of automatic setters are available. Discuss your requirements with a supplier.

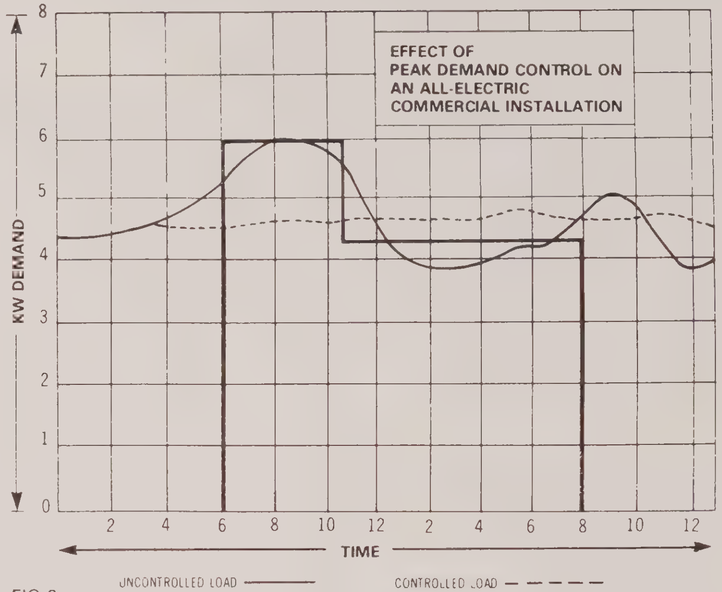


FIG 2

BASIC CONTROL OPERATION

FIG 3

1. Building load exceeds demand setting at A and control removes load at B* to prevent high demand reading.
2. Building load drops at C and control adds enough load at D* to maintain maximum usage of demand.

*Control action is delayed to ensure optimum operation and minimum switching

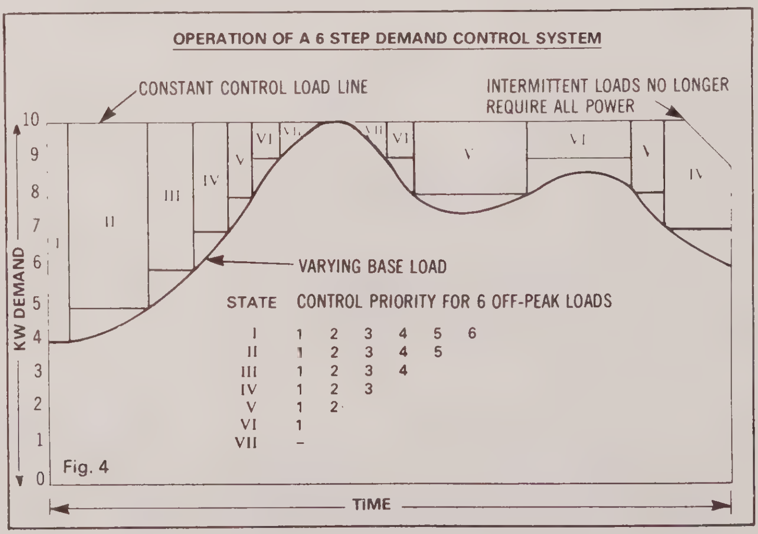


Fig. 4

dollars will have been virtually halved.

To illustrate the principle, assume that two machines of 100 Kw capacity are each run for an hour simultaneously as part of a production process. At $2. per Kw the demand meter will register 200 Kw and the demand portion of the bill will total $400.

However, if production is now rescheduled to run each machine sequentially so that only one machine is on at one time, the meter will stay at a peak of 100 Kw—and the demand charge will again be cut in half. Obviously, the answer is to reduce the peaks and valleys in power usage.

Controlling demand peaks.

With a good idea of the demand regime for the plant, control procedures may either be implemented manually (see case histories) or using one of the peak load controllers or shedders available on the market. While the case history of a demand controller shows a capital cost of $60,000, models are available at much lower cost suited to the requirements of many small to medium size plant operations.

Load shedding as demand increases, and addition of load as demand is reduced, are carried out automatically and with a predetermined priority which establishes which loads should first be shut down—frequently for only a few minutes at a time.

The graph shows the effect of peak load shedding in an all electric industrial building where operations were not in any way effected by the automatic shutting off and scheduling of electrical loads to reduce demand and where installation of the equipment paid for itself in less than two years.

It hasn't arrived yet, but look to the future for remote automatic, meter reading which will allow the utility to perform this peak shedding function on behalf of the company. The hardware necessary is already in existence and widespread tests in both domestic and industrial situations are underway.

Variable speed drives for motors—one new frontier.

Necessity is the mother of invention. And as energy prices continue to climb, more and more new developments in energy conservation technology and hardware will come forward onto the market. It will take industrial engineers and plant managers with open minds to accept these developments and put them to work saving energy in Canadian plants.

A case in point are solid state variable speed drives for motors and pumps now available on the market. There is certainly little question that they are needed. In industrialized areas, motors consume about 50% of the total electrical load, and a larger percentage of the industrial load (in the pulp and paper industry, for example, motors consume more than 90% of the industry load). And very few of these motors function at anywhere near their rated loads.

The result is wasted energy and higher power bills. There are other variable speed drives (slip couplings or resistance controls, etc.). But while these devices reduce speed, they simply dissipate the excess energy required by the load in the form of heat.

Working with wound rotor motors, the solid state regenerator recovers up to 97% of unneeded energy, processes it through a converter and returns it to the utility supply. In the case of a wound rotor motor operating at 70% speed, efficiency can be raised a full 23%, from 59% to 82%.

There are a multitude of potential applications on pump and wound rotor motors, but a prime industrial use is in replacing variable inlet vanes or dampers in variable air volume conditioning systems which require fans to run at constant full speed.

The gain in energy efficiency—as shown in the chart—is dramatic. And while these devices cannot be used with cheaper, conventional "squirrel cage" motors, future economics may well dictate retrofitting both new motors and controls.

Distributors of these controls meet resistance because the solid state non-mechanical nature of these motors is new to many industrial engineers—even though at $80 per hp on a large motor (up to $500 per hp on a smaller motor) additional costs can quickly be recovered through energy savings.

With built-in power factor correction and current limiting, the controls offer substantial potential energy savings in a number of industrial and

other applications—one estimate is from 500 to 4,000 Kwh per horsepower per year on a motor—but only if they are accepted as 'state of the art'' and used in both new and retrofit applications.

Each plant offers opportunities.

The materials management characteristics of each industry are so different that it is difficult to be specific about the types of programs that can be carried out to optimize production and energy consumption in a given plant. There is no question, however, there are many opportunities to cut both energy demand and billing if sufficient attention is given to the situation.

In many cases, the techniques under consideration will have far reaching enough effects that many departments of the company will need to be deeply involved in the planning process—perhaps through their representation on an energy conservation committee.

For instance, if it appears that a 2-day, 24-hour operation to produce a particular component is more energy efficient than a sporadic program stretched over one shift and five days, it is essential that other factors such as the labour costs and the cost of space to store the stocks of product be factored into the decision.

Once again, there are many trade-offs which must be considered. But they need not become a barrier to energy conservation. If experience of other energy conscious firms is any guideline, trade-offs are merely factors which are useful in selecting an order of priorities for energy projects as part of an ongoing assessment of the company's performance.

Even more fundamentally, for each industry there is a unique relationship between energy use and productivity. In the chemical industry, for example, it has traditionally been said that 95% of the energy is utilized to make 75% of the product. In other words, the ''fixed'' costs of providing a base load of energy (i.e. lighting and heating the plant and setting processes and equipment in motion) are such that the last 25% of production consumes only 5% of total energy used.

Obviously this rule of thumb would vary from industry to industry depending on both the nature of the manufacturing process (for example, continuous vs batch processing) and its energy intensity. And it may well be that advancements in more energy efficient processes and equipment may change the ratios involved to some extent. Nevertheless, it is important before major production changes are made that this fundamental relationship between energy consumption and production be well understood.

Many of the examples in the following case history section depict situations in which there was no effect on production rates. They represent the first opportunity to carry forward the energy conservation banner and to set the stage for more fundamental changes which may be justifiable now or in the future.

CASE HISTORIES

Automatic lubrication saves energy

The situation: At a cement plant in the United States, manual lubrication practices were being used on two major applications with associated wastage of lubricant (and the energy consumed in producing the lubricant). The company also felt that maintenance costs could be reduced and equipment life stretched via an improved lubrication system.

Action taken:

1. On three grinding equipment gear trains, equipment had been manually sprayed with gear compound every two hours using 4,350 gallons of lubricant per year. An automatic oil-mist system now uses only 150 gallons per year.
2. An automatic lubrication system on a group of seven clinker breakers reduced lubricant consumption from 3,600 gals/year to less than 200 gals/year.

Energy/dollar savings:

1. (4350 − 150) gals/yr × 8 lb/gal × 0.2725 $/lb = $9,100 year
2. (3600 − 200) gals/yr × 8 lb/gal × 0.40 $/lb = $10,900/year

Total = $20,000/year

Cost of improvement: Not available.

Recommendation: Consider automatic lubrication equipment as a means of saving lubricant costs. In the above case, assuming 0.140 MBtu/gal were consumed in producing the lubricant, actual savings in energy would have been more than 1075 MBtu/year.

Automatic replaces manual shutoff on punch presses

The situation: In a General Motors manufacturing facility, shutdown of punch presses during a workshift was manually controlled and at the discretion of press operators.

Action taken: A normally closed, time delay to open relay (10-15 minute delay) was inserted in main motor control circuits of 54 presses to automatically shut off the punch press main motor when the press is not cycled within the pre-set time period. The operator restarts the press motor at the press control panel.

Energy savings: Estimated at 913,000 Kwh for 54 presses.

Dollar savings: 913,000 Kwh @ $.025 Kwh = $22,825/year.

Cost of improvement: $2,400 including labour.

Recommendation: Look to automatic controls of a number of different types to shut down energy consuming electrical equipment whenever it is not required.

Cam controller on compressed air saves money on die cleaning

The situation: A continuous stream of 100 psi air was used to blow scale and dirt from dies in a General Motors press operation. This compressed air was actually required for only a brief instant during the press cycle and the air provided but not required, represented a substantial energy and dollar waste.

Action taken: Cam controls were installed to activate a short blast of air only as required during pressing operation.

Energy savings: Previous compressed air consumption: 6240 cfh x 8 machines = 49,920 cfh
Present compressed air consumption: 1560 cfh x 8 machines = 12,480 cfh
Savings: 49,920 — 12,480 = 37,440 cfh x .00598 = .2239 MMBtu/yr

Dollar savings: 860 MMBtu/year @ $.025 kwh = $6,250./year.

Cost of improvement: $85. per machine = 8 x $85 = $680.

Recommendation: Whenever controls can be installed to make more efficient use of compressed air significant energy and dollar savings are possible. A further suggestion would be installation of volume meters on air supply lines to specific pieces of air activated equipment to permit the operator to determine optimum air use.

Capacitor additions improve power factor

The situation: At a Wallaceburg, Ontario plant of Libby, McNeill and Libby, a bank of manually operated capacitors rated at 240 KVAR had been installed in 1957 in an effort to improve power factor. Management realized, however, that this capacity was no longer adequate to handle plant demand and power factor had dropped below 80 percent. A penalty is incurred on the power bill from the local utility when power factor at this plant drops below 90%.

Action taken: The company installed an additional 120 KVAR of capacitors with automatic switching leaving the existing capacitor bank permanently connected.

Energy savings: None.

Dollar savings: Without the capacitors, the company would have incurred a power factor penalty of $5,025/year.

Cost of improvement: $8,050. A discounted cash flow rate of return analysis established a rate of return of 32% and a payback of 3.1 years. "Simple payback" would be in less than two years.

Recommendation: Even if your plant has capacitors installed to correct power factors, keep a watchful eye on utility bills to ensure that power factor penalties are not being incurred as plant equipment is expanded.

Capacitors, control panel improve lagging power factor

The situation: Management at the Candiac, P.Q. plant of International Harvester Limited were aware that economic penalties were being incurred due to a lagging power factor averaging 87%.

Action taken: The company installed five 30 KVAR capacitors and an eight step control panel to raise power factor to 95% and eliminate the penalty paid to Hydro Quebec and reduce consumption by minimizing line and transformer heat losses. In the latter case, installation of capacitors reduces the reactive component of current in the line which does not perform useful work—merely generating heat which is ultimately dissipated to the environment.

Energy/dollar savings: Elimination of power bill penalty = $1,132/year. 7% reduction in line and transformer heat losses = $1,534/year.
Total savings = $2,666/year

Cost of improvement: $7,500.

Recommendation: Look to use of capacitors or synchronous motors to reduce power factor and avoid penalties on electric power bills.

Lower temperature, conveyor speed set in paint ovens.

The situation: At a Buick plant in the United States, prime paint ovens were being run at an excessively high speed and temperature without offering any greater product quality. Conveyor speed was also higher than needed to meet actual production requirements.

Action taken: Conveyor speed in the drying ovens was reduced and temperatures were lowered to compensate for the reduced speed.

Previous Consumption:
Operating: (5,300 cfh) × (1,000 Btu/cf) × (16 hrs/day) × (230 days/yr) = 19,504 MMbtu/yr.
Idle: (530 cfh) × (1,000 Btu/cf) × (8 hrs/day) × (230 days/yr) = 975 MMBtu/yr.
Total: 20,479 MMBtu/yr.

Present Consumption:
Operating: (4,500 cfh) × (1,000 Btu/cf) × (16 hrs/day) × (230 days/yr) = 16,560 MMBtu/yr.
Total: 17,388 MMBtu/yr.

Energy Savings: 20,479 MMBtu/yr — 17,388 MMbtu/yr = 3,091 MMbtu/yr.

Dollar Savings: 3,091 MMbtu/yr = 3091 Mcf @ 2.00/Mcf = $6,182/year.

Cost of program: Nil.

Recommendation: Question oven and process temperatures and rates of production that have "always been that way". Substantial savings are available by tailoring the system to precisely defined production and quality requirements.

Manual rescheduling lowers peak demand

The situation: A U.S. plant operated a group of twelve 30K resistance heated furnaces, each of which draws its full 30K load for two hours after being turned on then falls back to a temperature holding rate of 10 Kw. All furnaces go through one cycle of heating up, holding, and cooling every 24 hours and management was concerned to schedule furnace use so that peak owner demand — and demand charges — could be reduced.

Action taken: A schedule of furnace use was established so that no more than two furnaces are on heat-up cycles simultaneously.

Energy savings:
Where all 12 furnaces heat-up simultaneously:
Peak demand = 12 furnaces × 30 Kw/furnace = 360 Kw.
Where 2 furnaces heat-up simultaneously and the remaining 10 furnaces are on hold:
Peak demand = (2 furnaces × 30Kw/furnace) + (10 furnaces × 10 Kw/furnace) = 160 Kw.
Peak demand reduction = 360 Kw − 160 Kw = 200 Kw.

Dollar savings: 200 Kw × $1.50/Kw/mos × 12 mos/yr = $3,600/year.

Recommendation: With or without the use of automated peak demand controllers, substantial savings on electrical demand changes can be achieved through productive scheduling of equipment use.

No time between shifts improves efficiency

The situation: At a General Motors van plant, an hour time elapse was scheduled between the 1st and 2nd shift during which consuming equipment was allowed to run.

Action taken: The plant was put on a "butt shift" operation which eliminated the one hour excess operating time for plant equipment.

Energy Savings: 35,000 MMBtu per year in natural gas and electricity.

Dollar Savings: 35,000 MMBtu/yr @ (approx) $2.00/MMBtu = $70,000/year.

Cost of Improvement: Nil.

Recommendation: More efficient scheduling of shifts, or elimination of half shifts or unneeded shifts can have a major impact on energy costs. Unproductive time in which equipment is allowed to run brings dramatic increase in power bills — along with a higher cost of energy per unit of production. Another possible solution where "butt shifts" cause traffic problems would be load cycling via a mini-computer.

One coat paint cuts energy use, maintains quality

The situation: At the Welland, Ontario works of John Deere Limited, an energy audit and subsequent calculations pointed to major potential energy savings in the two-stage paint system for metal and other parts — without affecting product quality.

Action taken: During a scheduled summer shutdown, and without interrupting production, the company constructed a one stage paint system — obviating the need for a prime paint oven which had consumed 2,565 lbs. of steam per hour. At the same time, the 160°F washer dry-off oven was changed from 100 percent exhaust to a recirculating system which re-uses 80 percent of the 47,000 cfm exhaust air.

Energy savings: 44 percent overall, or 32,000 MMBtu/yr.

Dollar savings: $64,000/yr.

Additional savings due to elmination of prime paint and solvent in the priming stage amount to $142,000/yr. Total savings: $206,000/yr.

Cost of improvement: Total investment was $274,000, including direct and indirect costs. Discounted cash flow calculations gave a return on investment of 53 percent with a cash payback period of 17 months.

Recommendation: Give thought to simplifying and redesigning production systems to optimize energy usage and reduce waste. In John Deere's case, the new system is not only energy efficient, it takes up considerably less floor space and has increased production capacity by 56 percent.

Peak demand controller cuts demand — and consumption

The situation: Facing consistent increases in the cost of electric power, and orthodox rate structure reflecting both demand and consumption, the Davenport/Royce/Ward Street complex of Canadian General Electric was a prime candidate for peak load — and power bill — reduction.

Action taken: The company installed an automatic peak load controller which reduced the complex's peak electrical load by 1,000 Kw. Reduction in electrical demand was achieved by the controller scheduling certain equipment (furnaces, ovens and refrigeration system) to operate only on off-peak hours — late afternoon and evening. Other devices, such as moulding machines and room air conditioners are cycled for short periods during peak demand hours without affecting production requirements. A an added benefit, the controller assists in reducing wasted energy consumption on nights and weekends — by automatically turning off lights and air conditioners in the various plant and office buildings.

Energy savings: Due to reduced demand: 1 MMKwh.

Dollar savings: Reduction in demand charges = $50,000.
Reduction in energy = MMKwh = $7,600
Total savings: = $57,600.

Cost of improvement: Not available.

Recommendation: Explore the possibility of a peak demand controller to reduce demand charges and reduce demand. Manufacturers supply many models smaller than the one used by General Electric. If a peak demand controller does not fit with your company's plans, see what can be done to reduce peak demand by non-automatic scheduling of loads within the plant.

Peak power program lowers bills, conserves electric power

The situation: The Sudbury area plants of Inco Limited use both 25 and 60 cycle power. Approximately 12,000 Kw of 25 cycle and 220,000 Kw of 60 cycle power is purchased from Ontario Hydro. Additional power is supplied from two local 25 cycle hydraulic plants owned by Inco and with an installed capacity of 30 MW and 3 other company-owned 60 cycle stations with an installed capacity of 19 MW. Inco also has two 9 MW steam turbines which utilize waste heat, located in the company's Iron Ore Recovery Plant.

Due to expected future increases in the price of electric power, the Utilities Dept. began an electric power cost reduction program. The two main elements of this program involved increasing the efficiency of the hydro-electric plants and a program of peak power control.

Action taken: Before carrying out the program of peak power control, approval was first obtained from senior management because of an expected affect on production. Load analysis using graphic meters was carried out at each individual plant and mine and discussions were held with the management of each plant to examine how peaks could be lowered by

re-distributing loads. Load re-distribution was carried out at no cost.

It was found that to properly control the peak, it was essential to be able to predict the peak for a given month. At the end of each month each of the plants is contacted to obtain its production schedule for the following month. Based on this information as well as on the availability of equipment for peak control, the peak for the following month is set. The peak is then maintained by the power system operator. To aid the operator a digital demand monitor which shows the purchased power consumption was installed. The operator maintains the peak by using generation and shutting down equipment as required.

Energy/Dollar savings: Peak control does actually conserve purchased energy in the Inco program. Permission is required from the system operator to start large machines (over 500 HP) and these machines are run only when required. The program has also made people aware of the cost of electric power and has encouraged them not to waste it. In the third year of the program, electric energy cost reduction programs, with the peak power control program as the major portion, resulted in savings in excess of $1 million.

Recommendation: Reduce peak loads either by scheduling or automatic load shedding controls. The latter are available in a range of sizes for both small and large power consumers.

Inco plans call for a more detailed understanding of energy use patterns, and the company has installed digital pulse metering equipment on sources of power and uses portable equipment to monitor loads. Computer programs have been developed to aid in analyzing loads.

Smaller hammermill improves grinding efficiency

The situation: At the Cannington, Ontario plant of Griffith Laboratories, the company was faced with modernizing a 24 hr/day production line for ground cereal products.

At the heart of the original system was a large, high speed hammermill driven by a 75 hp electric motor. It was felt that this larger mill was consuming excessive amounts of energy.

Action taken: As part of the revamping, management replaced the larger mill with a smaller, more efficient hammermill requiring only 10 h.p. Aside from lowering power consumption, the new machine produced a more homogeneous and acceptable product.

Energy savings: 75hp − 10hp = 65hp, × (24 hrs) × (.746) = 1164 Kwh/day. 1164 Kwh/day = 5 days/wk × 52 wks/yr × 302,640 Kwh.

Dollar savings: 302,640 Kwh @ $.025/Kwh = $7,566/year.

Recommendation: When looking to replace plant equipment, do not accept previous specifications at face value unless they appear to have been arrived at by a detailed assessment of the actual process requirements.

Synchronous motor improves power factor

The situation: At an oil field miscible flood installation in Western Canada, three large induction motors (total 2,600 hp) and a number of smaller auxiliary motors with a collective rating of 1,500 hp were installed. The plant also included a 1,750 hp synchronous motor driven compressor which was specified to be capable of operating at 80 percent leading power factor and is normally adjusted to reduce the total plant load to 5152 KVA at 92% power factor.

Action taken: Installation of the synchronous motor, reduced increased power factor considerably as per the following analysis: total Kw load of motors = 4,699 Kw. Lagging KVAR's due to inductive motors = 3,063 KVAR. Leading kVAr's supplied by synchronous motor = 1,027 KVAR. Resultant lagging KVAR = 3,063 − 1,027 = 2,036 KVAR. Total KVA demand = $4{,}699^2 + 2{,}036^2$ = 5,121 KVA.

$$\text{Power factor} = \frac{4{,}699\ \text{Kw}}{5{,}121\ \text{KVA}} = 92\%$$

Energy/dollar savings: No energy savings. With the synchronous motor, monthly billing would have been the greater of 4,699 Kw, or (0.9 × 5,121 KVA) = 4,609 Kw. Billing on 4,699 Kw = $24,899/year.

With a 1,750 hp induction motor used in place of the synchronous motor, total KVA would have been 6,294 at 75% power factor = \$29,823/year. The saving on energy billings is \$29,823 — 24,899 = \$4,924/month.

Cost of improvement: Extra cost for synchronous motor.

Recommendation: Consider the use of synchronous motors along with other possible steps (see booklet text) to improve power factor and reduce electrical bills.

Turning off furnaces on third shift cuts energy usage

The situation: At a Chevrolet plant in the U.S. eight gas-fired high heat coil spring forming furnaces were kept hot (1400°F) during third shift with no production.

Action taken: Furnaces are now turned off at the end of the second shift and relit at the beginning of the first shift the next day.

Energy savings: Previous Consumption: 3000 cfh × 24 hrs × 250 days × 8 = 144 MMcf/yr.
Present Consumption: 3000 cfh × 19 hrs × 250 days × 8 = 114 MMcf/yr.
Savings = 30 MMcf/yr.

Dollar savings: 30 MMcf @ \$2.00/Mcf = \$60,000/year.

Cost of improvement: Nil.

Recommendation: Endeavour to ensure that process or other equipment consumes energy only when it is making a productive contribution to plant output. Turning off equipment can turn down your power bills. Where furnaces require warm-up time, consider the use of cam controllers.

Tips for saving money through production optimization

1. Shut down process heating equipment when not in use.
2. Indicate causes of electrical power demands and peak charges and reschedule plant operations to avoid peaks.
3. Reduce temperature of process heating equipment when on standby.
4. Use most efficient equipment at its maximum capacity and less efficient equipment only when necessary.
5. Heat treat parts only to required specifications or standards.
6. Schedule routine maintenance during non-operating periods.
7. Consider three or four days around-the-clock operation rather than one or two shifts per day.
8. Minimize operation of equipment required to be maintained in standby condition.
9. Reduce operating time of equipment to that actually required.
10. Optimize production lot sizes and inventories.
11. Turn off conveyors, lift trucks, etc., when not in use.
12. Recharge batteries on materials handling equipment during off-peak demand periods.
13. Adjust and maintain fork lift trucks for most efficient operation.
14. Shut down diesel construction equipment when not needed.
15. Use optimum size and capacity equipment.
16. Upgrade conveyors.
17. Use gravity feeds wherever possible.
18. Schedule baking times of small and large components to minimize use of energy.
19. Use continuous equipment which retains process heating conveyors within the heated chamber.
20. Convert from batch to continuous operation.
21. Minimize unessential material in heat treatment process.
22. Change product design to reduce processing energy requirements.
23. Reduce scrap production.
24. Upgrade obsolete or little used equipment.
25. Install capacitors — or use other means — to improve power factors and avoid billing penalties.
26. Control peaks and valleys in electrical demand to improve load factor.
27. Look to manual controls or automatic load shedders as a means of reducing peak electrical demand.
28. Consider variable speed drives for round wound motors.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg{\cdot}m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	1° = (π/180) rad
minute (of arc)	′	1′ = (π/10 800) rad
second (of arc)	″	1″ = (π/648 000) rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY THROUGH COMBUSTION CONTROL 5

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SAVING MONEY THROUGH COMBUSTION CONTROL 5

Saving money through Combustion Control

Introduction:

Virtually every industrial enterprise has boilers, furnaces and other combustion equipment such as kilns and ovens. This booklet is designed to help Canadian companies to maximize the efficiency of combustion processes — and, as a result, to save substantial amounts of energy and money.

The potential also exists in some plants to utilize waste material as a source of heat. And to help foster implementation of waste utilization systems, a section of the text deals with applications for pyrolysis incinerators.

Furnaces, Kilns, and Ovens

Roughly eleven percent of the nation's energy is used by industry for "direct heating" (not including indirect heating by steam). The majority of this energy is used by large plants in heavy industry such as primary metals, oil refining, or cement manufacturing. However, much of this energy is used by smaller organizations to heat treat metal parts, fire ceramics, dry paint, bake bread, and many other heating operations. This section is intended to describe how one can save energy in furnaces, kilns, and ovens.

In small energy-intensive organizations, the energy audit will quite frequently show that much of the energy is going to one or more pieces of direct fired equipment such as a furnace, kiln, dryer, etc. The success of an energy management programme will then depend on the decisions as to just what steps are most appropriate for energy savings in these pieces of equipment.

Making such decisions, and making them intelligently, is not something that can be done by any simple rule-of-thumb. Of course, check-lists can be used which describe the possible steps for increasing the energy efficiency of heating equipment, but nothing in such lists weighs the relative importance of the various check-list items. In other words, in one installation the most important first step may be adjusting the air to fuel ratio, in another the lack of insulation may be the important factor, and in a third it is possible that no major energy saving programme is justified.

The tool which will enable one to estimate the amount of energy which might be conserved and will point out the best ways of doing it, is the heat, or energy, balance. It will permit the translation of measurements and calculations to dollars of fuel savings.

Heat balances and how to use them

A heat balance is simply a measure of efficiency — a listing of the energy in all forms that enters a system over a given period of time (the input) and a similar listing of the energy that leaves (the output). Since energy is neither created nor destroyed, the input and the output must be equal.

For an energy management programme, a heat balance on a critical furnace or oven serves several purposes.

- It will show how much of the energy input was actually used for the intended purpose, e.g., to heat the product, to drive off water, etc. This figure may be interpreted as the energy efficiency of the system; it is in practice often as low as 2-5%.
- It will show how much of the energy is lost to the atmosphere or perhaps to a cooling pond. This, of course, represents energy savings that are theoretically possible.
- If the heat balance is reasonably well done, it will show also how the heat loss occurs. Some will be carried out with the product, some lost up the stack, some radiated to the surroundings from the furnace walls, etc. This information furnishes clues as to where one should look for the most important energy conservation possibilities.
- Most important of all, a heat balance is by far the best tool which one can use to estimate the

energy and cost savings which can be achieved by some change in process or equipment that is proposed as an energy saving investment. It will also enable one to identify the most valuable of several conservation proposals.

As an illustration, consider a simple system for the job of heating a pint of water from 72°F to boiling using a heavy cast iron skillet on the large burner of a kitchen stove. Tests show that it requires two cubic feet of gas, or 2000 Btu's to do the job. This 2000 Btu is the input energy to the system. The system output is in three parts. The energy needed to heat the water from 72°F to 212°F can be calculated at 140 Btu, while the energy necessary to heat the 3.5 pound skillet is about 60 Btu. The third output, some 1800 Btu, must be the energy in the hot combustion products which was lost to the atmosphere of the kitchen. The efficiency of this system is 140 Btu divided by 2000 Btu, or 7%.

A more efficient system than this would use a glass laboratory beaker as the container and a small electrical immersion heater as the energy source. The heat to the container would be cut to 10 Btu, and the loss to the surrounding air to about 50 Btu, requiring an input of electrical energy on only 200 Btu. Assuming that about 600 Btu of fossil fuel was required to generate this electricity, the efficiency has been increased to 140 Btu divided by 600 Btu, or 23%.

The important point of the above illustration is that the heat balance permitted the identification of the most important of the energy losses — the large amount of energy escaping around the skillet. It does not, however, mean that resistance heating is more efficient than fossil fuel fired heating.

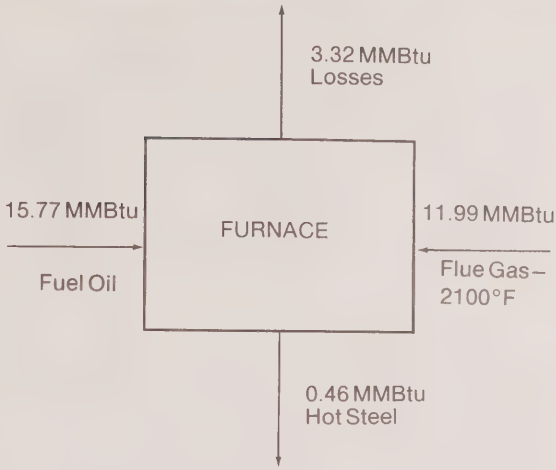
Improvements to a furnace—an example.

As an industrial example of this priciple, an oil-fired furnace heats one-ton batches of steel to 2000°F for a forging operation. It burns 95 gallons of #2 fuel oil during each two-hour cycle. The stack temperature is 2100°F, and an analysis of the flue gas shows an oxygen content of 11%, equivalent to 100% excess air.

The only energy input to this system is the burning fuel oil. At an energy content of 166,000 Btu per gallon for # 2 oil,

Input = 166,000 Btu/gal × 95 gal = 15.77 MMBtu.

1st Heat Balance—Batch Fired Furnace



This same quantity of energy must also leave the furnace during each cycle; it does so in three forms:

1. The heat content of the steel is the weight of steel times its temperature increase times its specific heat of 0.12 Btu/lb°F = 0.46 Btu.
2. The stack loss represents the energy escaping in the hot flue gas. Referring to the chart, note that at a stack temperature of 2100°F, and with 100% excess air, the stack loss is 76% of the fuel burned.
   Stack loss = 15.77 MMBtu × 0.76 = 11.99 MMBtu.
3. Conduction and radiation losses from the furnace walls and roof must make up the remainder of the energy output.
   Wall losses: 15.77 − (11.99 + 0.46) = 3.32 MMBtu.

Output = 0.46 + 11.99 + 3.32 = 15.77 MMBtu per cycle.

It is evident in this heat balance that most (76%) of the energy is wasted up the exhaust stack. Looking again at the chart, one can observe that the stack loss is least when the amount of combustion air is precisely the amount required to completely burn the fuel. If large amounts of excess air are supplied, the energy of the fuel is mostly used to heat the air, and the stack loss becomes very large. Conversely, of course, if insufficient air is supplied, the fuel will not be completely burned and energy will again be wasted. A reasonable quantity of excess air

when burning fuel oil is about 20%, or when burning natural gas about 5-10%.

Excess air can be reduced by adjusting the burners, by throttling the air inlets, and by repairing cracks, holes, and ill-fitting doors. The stack damper should also be adjusted to maintain a very slight positive pressure in the fire-box to prevent the infiltration of unwanted air. The goal of 20% excess air is reached when the flue gas analysis shows 3-3.5% oxygen and 11.5-12% carbon dioxide.

At 20% excess air, the chart shows that the stack loss is only 46% of the fuel energy instead of the original 76%. The energy absorbed by the steel remains at 0.46 MMBtu per cycle, and the loss from the walls and roof is still 3.32 MMBtu. This total, 3.32 + 0.46 = 3.78 MMBtu, is now 54% of the total input (100% − 46% = 54%). The total fuel energy needed per cycle is therefore:

3.78 MMBtu / 0.54 = 7.00 MMBtu

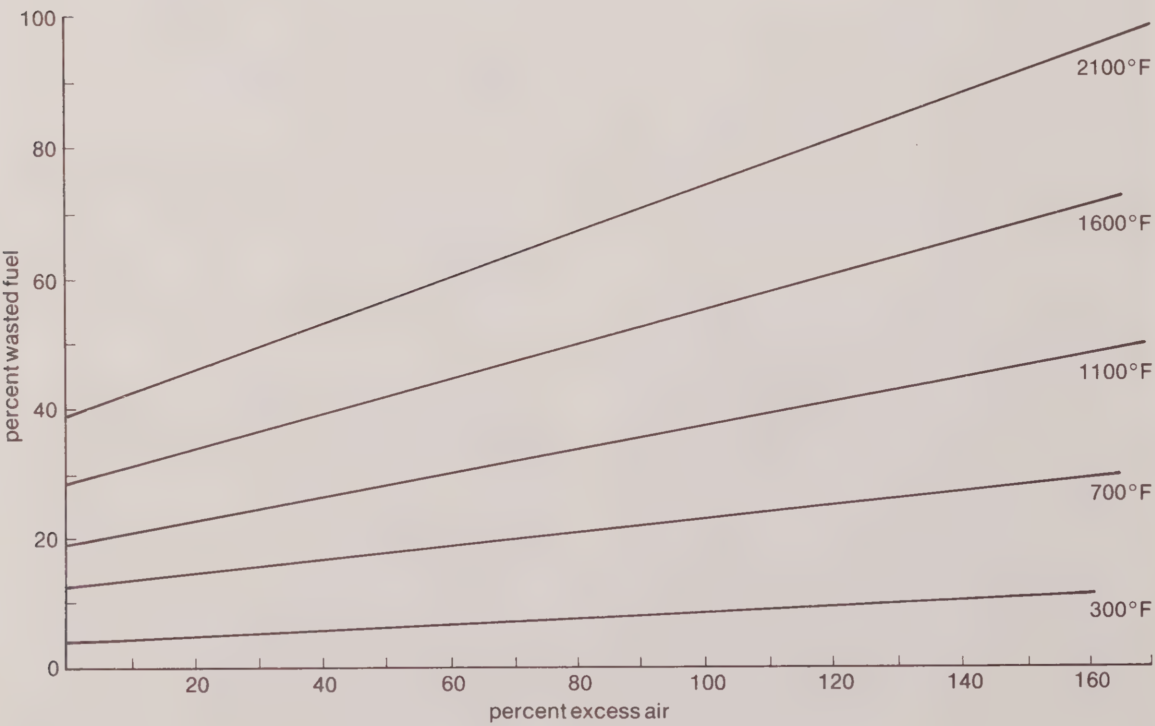
2nd Heat Balance

Input	*Output*
7.00 MMBtu	Steel − 0.46
= 42.3 gal (U.S.)	Stack − 3.22
of oil	Walls − 3.32
	Total − 7.00 MMBtu

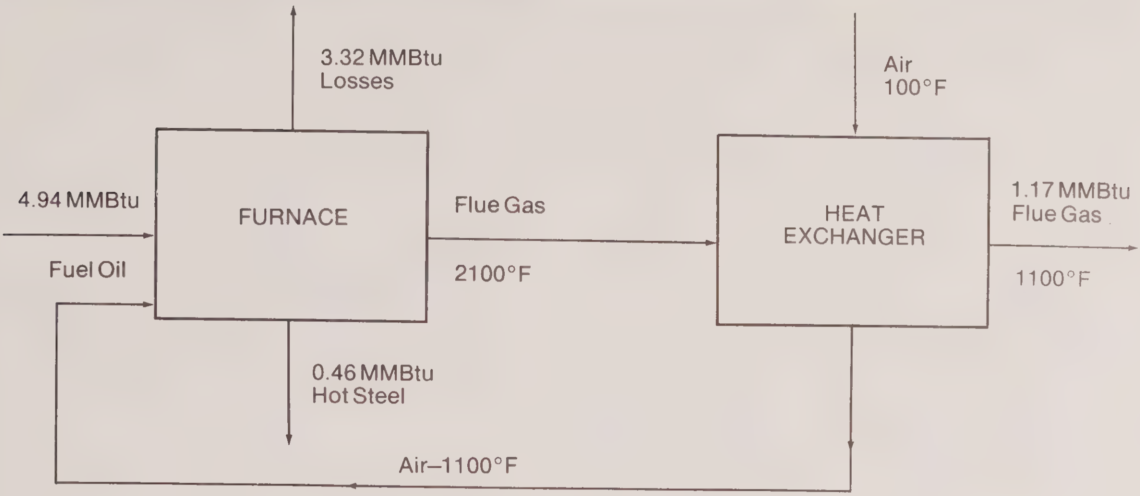
In the previous heat balance, even after adjusting the excess air to the practical minimum, energy is being wasted up the stack at the rate of 3.22 MMBtu per cycle, or at 500 cycles per year, 1365 MMBtu per year. With oil at 50¢ per gallon (U.S.), this is a dollar loss of $4,850 per year.

Some of this heat can be recovered by passing the flue gas through a heat exchanger, or through a waste heat boiler. The recovered heat can be used for a variety of purposes; following are some of those frequently suggested:

Stack Loss vs. Excess Air at various stack temperatures



3rd Heat Balance–Batch Furnace with Preheated Combustion Air



- Make steam for process use, for electrical power generation, or for space heating.
- Heat water for processing or for space heating.
- Preheat combustion air for the furnace.
- Preheat the product entering the furnace.
- Heat air for space heating.

The best use for the recovered heat depends on the process and the particular plant conditions. In this case, with a batch furnace and possibly a rather uneven schedule, preheating the combustion air might be the best use. A diagram showing the heat flow with such an arrangement is shown as a 3rd heat balance. The numbers are MMBtu's of energy for a two hour furnace cycle.

To estimate the fuel usage under these conditions, consider the entire diagram as a single system with one heat input (the air at 100°F is considered to carry no heat), and three outputs. Two of the outputs are the heat in the steel, and the conduction losses. These outputs total 3.78 MMBtu as in heat balance No. 2. The third output is the waste flue gas at 1100°F. (Since the mass of flue gas is approximately equal to the mass of combustion air, it is reasonable to estimate that if the air is heated by 1000°F, the flue gas will be cooled by the same amount.)

According to the chart, at 20% excess air and a stack temperature of 1100°F, the stack loss is 23.5% of the fuel fired. The other two outputs, the 3.78 MMBtu for conduction losses and for the hot steel, must therefore, amount to 100% − 23.5% = 76.5% of the fuel.

Fuel energy = 3.78 × 1/0.765 = 4.94 MMBtu per cycle.

Stack loss = 4.94 × 0.235 = 1.17 MMBtu per cycle.

At this point, the largest energy loss in the system is the 3.32 MMBtu lost by conduction and radiation through the walls and roof of the furnace. Assume that suitable repair or addition to the insulation can reduce this loss to 1.70 MMBtu per cycle. A new heat balance performed as shown above determines that this will reduce the fuel input to 2.82, and the stack loss to 0.66 MMBtu per cycle.

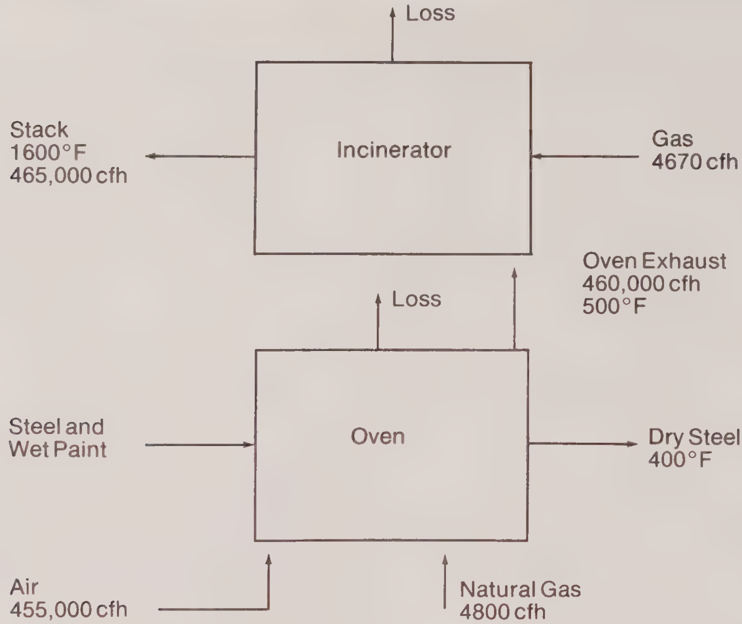
SUMMARY TABULATION
MMBtu per TWO HOUR CYCLE

	Input MMBtu	Stack Loss	Conduction Loss	Heat in Steel	Efficiency
1. Original condition	15.77	11.99	3.32	0.46	2.9%
2. Reduce excess air	7.00	3.22	3.32	0.46	6.6%
3. Preheat air	4.94	1.17	2.72	0.46	9.3%
4. Add insulation	2.82	0.66	1.70	0.46	16.3%

Assuming a production rate in this furnace of 500 cycles per year, and an average fuel oil cost of 50¢ per gallon, the yearly cost of energy under the four different conditions is as follows:

1. Original condition	$23,750
2. Reduce excess air	10,540
3. Preheat air	7,440
4. Add insulation	4,250

Conventional Paint Dryer and Fume Incinerator



Obviously, these changes were not all of equal importance. By far the most important was the reduction of excess air from 100% to 20%. This single change saves $13,210 per year, and the capital cost involved is quite minor.

The next change, that of preheating the air, produced a smaller savings of $3,100. The cost. of a heat exchanger, duct work, and probable burner modifications will vary widely with different installations. If, in this case, the cost were $2,500, it would be a very attractive proposition; a quotation of $10,000 would require some rather careful analysis before making the investment. If one assumes a continuing increase in energy costs even the latter figure might be within reason, however.

The third step, adding insulation, saved $3,190. The cost could be low if it consisted of the simple addition of some bats or blankets of ceramic fiber on the inside of the walls and roof, or higher if it required rebuilding of the entire furnace lining.

It is evident that there is no simple rule-of-thumb by which one can decide to take a certain series of energy saving steps in a specific order. Any intelligent decision requires a reasonable knowledgc of the current situation and an estimate of the savings possible for each proposed step.

A paint drying oven — a conservation case.

Some continuous kilns or ovens, such as those used for brazing, annealing, sintering, etc., may be treated in much the same fashion as a batch furnace when estimating an energy balance.

It is only necessary to translate all energy units into Btu's per hour or per minute instead of Btu's per batch or cycle. The principles of energy management in these kilns are exactly the same — maintain the minimum practical fuel/air ratio, insulate properly, and recover waste heat whenever possible.

Other kilns, such as those used for drying a product containing water or an organic solvent, may be more complex systems. For example, the paint drying kiln discussed below must use so much air to dilute the combustible solvent vapors that the stack gas carries almost 1000% excess air. In this case, it is not practical to get an accurate analysis of the stack gas, and a measurement of the air flow rate is necessary in order to estimate a heat balance.

Consider a continous paint drying oven which is fed with 10,000 pounds of steel per hour, covered with 600 pounds of wet paint. The paint is composed of 290 pounds of solvent and 310 pounds of paint solids. The air in the oven is heated to 500°F with natural gas, which

evaporates the paint solvent (1190 cubic feet of vapor), and raises the temperature of the steel to 400°F. A large amount of excess air is required in order to prevent the formation of an explosive atmosphere of air and solvent vapor; the usual requirement is 10,000 cubic feet of excess air per gallon (about 7.25 lbs.) of solvent evaporated. Air pollution regulations state that the hydrocarbon vapors in the oven exhaust cannot be discharged directly into the atmosphere. The exhaust, therefore, is led into an incinerator where more natural gas is burned to raise the temperature from 500°F to 1600°F. At this temperature the hydrocarbons are all oxidized to carbon dioxide and water, and may safely be sent up the stack. A flow diagram of the system is shown.*

Heat balance for a conventional paint dryer.

Input

Natural gas to oven	4.80 MMBtu/hr
Natural gas to incinerator	4.67
Solvent vapors*	5.33
Total	14.80 MMBtu/hr

Output

Hot dry steel	0.41 MMBtu/hr
Stack loss at 1600°F	12.90
Other loss and unaccounted	1.49
Total	14.80 MMBtu/hr

*Since the solvent has a heat of combustion of about 18,400 Btu/lb, it furnishes part of the energy of its own incineration which must be included as a part of the heat input.

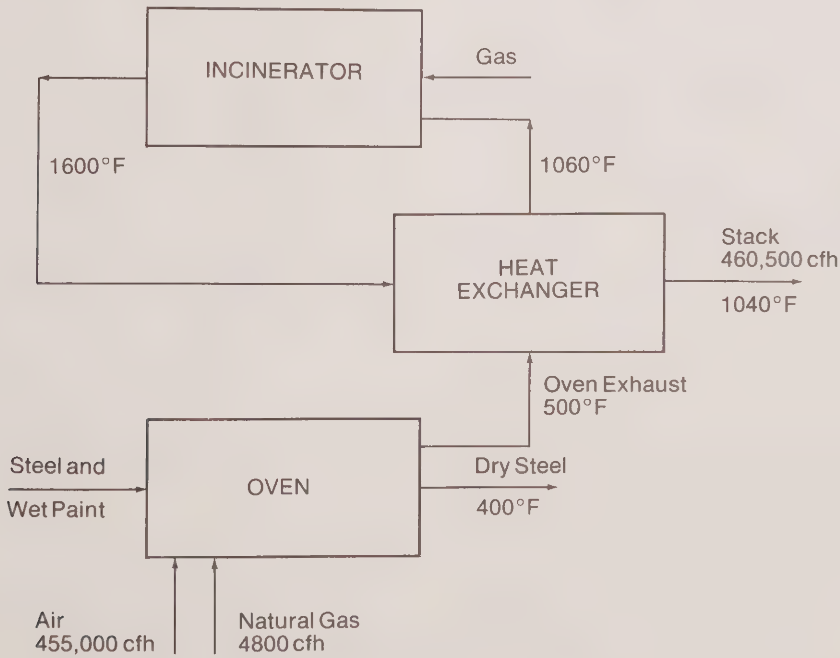
Inspection of this heat balance shows that the vast majority of the energy input, some 87%, is wasted as stack loss. Since this loss cannot be reduced by shutting down the incinerator, or by reducing the large amount of excess air, one must look for ways to utilize this waste heat. One technique is shown in the diagram, where a heat exchanger is used to recover part of the stack gas heat to preheat the overn exhaust before it enters the incinerator.

The following tabulation shows a heat balance on this new system:

Input

Natural gas to oven	4.80 MMBtu/hr
Natural gas to incinerator*	0
Solvent vapors	5.33
Total	10.13 MMBtu/hr

Paint Dryer, Fume Incinerator, and one Heat Exchanger



Output	
Hot dry steel	0.41 MMBtu/hr
Other losses	1.50
Stack loss at 1100°F	8.22
Total	10.13 MMBtu/hr

*A very small amount of fuel may be needed to assure that the gas stream ignites in the incinerator; i.e., a "pilot light".

Note that the addition of the heat exchanger and its accompanying duct work has reduced the use of natural gas from 9.47 MBtu/hr to 4.80 MBtu/hr. Assuming a natural gas cost of 2.00 per thousand cubic feet, and operation of the system for 4000 hours per year, the annual savings is

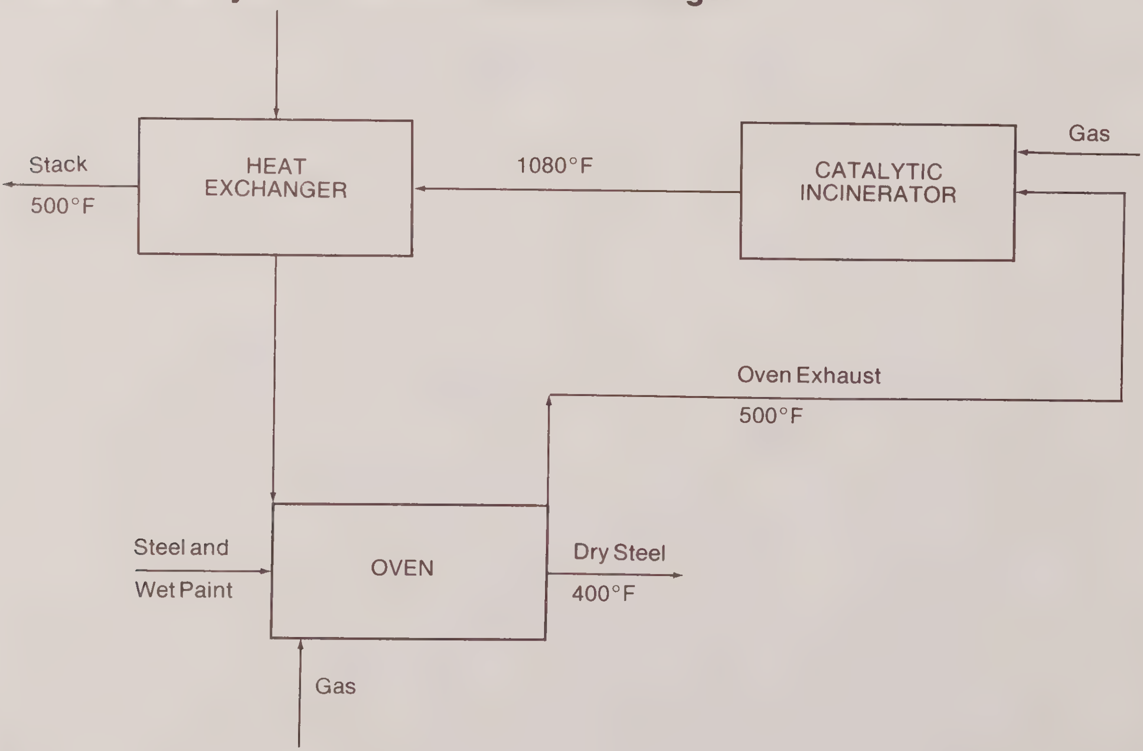
$$\frac{(9.47 - 4.80) \times 10\,\text{MMBtu/hr} \times 4000\,\text{hr/yr}}{1000\,\text{Btu/cf} \times \$2.00/\text{Mcf}} = \$37{,}300 \text{ per year}$$

Although the heat exchanger has reduced the amount of purchased fuel considerably, there is still a large amount of waste heat in the exhaust flue gas. It is possible to use this heat by installing a second heat exchanger and using it to preheat the incoming air to the oven up to 600°F. This will require some modifications perhaps to the air distribution system within the oven, but it will do away completely with need to fire natural gas to the oven except during warm-up or when operating at very low product/throughput. At normal production, all the heat is furnished by burning the solvent vapors in the incinerator.

Another method of conserving energy when incinerating hydrocarbon fumes, is to use a catalytic incinerator, similar in principle to the catalytic converters on the exhaust system of modern automobiles. Such a catalytic incinerator can save energy because the fume combustion is carried out at much lower temperatures than the normal 1600°F. Statements by manufacturers mention temperatures as low as 400°F for combustion of hydrocarbon vapors in excess air. The diagram shows a possible use of such a catalytic converter to a paint drying oven.

A heat balance for this system indicates that no heat from natural gas is needed when operating at a normal load. The gas burners indicated on the diagram will be necessary only during start-up, or when not enough product is being dried to furnish solvent vapor to heat the system.

Oven with Catalytic Converter and Heat Exchanger



Input

Natural gas		0 MMBtu/hr
Solvent		5.33
	Total	5.33 MMBtu/hr

Output

Hot dry steel		0.41 MMBtu/hr
Evaporation of solvent		0.06
Stack loss at 500°F		3.61
Other losses		1.25
	Total	5.33 MMBtu/hr

Some catalysts are "poisoned" and cease to work properly, if the vapors contain sulfur compounds or heavy metals such as lead. This point should be checked with equipment manufacturers.

A third possible method of energy conservation in paint drying is the use of a patented incinerator which can produce an exhaust stream that is almost free of oxygen; 2% is reported. If this gas is used in the oven for heating the product, one can permit the concentration of solvent vapors to reach a much higher level without danger of reaching an explosive atmosphere. This means that the volume of gases to be circulated can be cut to about one-half, and that energy can also be saved in the electrical power needed to operate the fans and blowers.

A summary of the purchased cost of fuel for the three systems considered is as follows:

	Annual Fuel Cost(1)	Efficiency(2)
Fig. 4 Conventional Dryer	$75,700	4.2%
Fig. 5 Dryer & Heat Exchanger	$28,400	5.8%
Fig. 6 Catalytic Converter	(3)	11.6%

If the solvent dried from a paint film is valuable in itself, for reasons other than its fuel value, one should consider recovering it with an activated carbon tower instead of incinerating it. This will not, in general, constitute an energy saving, but may well be a financial gain. Some newer systems use a vacuum rather than heat to pull the absorbed solvent from the activated carbon, and are reported to use less energy than the older heating technique to recover the valuable solvent.

Drying ovens or kilns in general do not lend themselves to rule-of-thumb advice as to the best methods of energy conservation. Each kiln seems to have its own special features, and needs an individual heat balance in order to understand how best to conserve energy. Kilns almost inevitably, however, have large quantities of waste heat available. If this waste can be utilized for space heating, low pressure steam, hot water, etc., one can improve on the rather low efficiencies listed in the tabulations above.

(1) Assumes natural gas at $2.50 per thousand cubic feet, and operation for 4000 hours per year.

(2) Energy needed for the product divided by total energy, including that in the paint solvent.

(3) Natural gas is needed only during a start-up period, or when operating at a low production rate.

Opportunities for energy savings

There are, obviously, a wide variety of steps that can be taken to improve the efficiency of furnaces, kilns and ovens. What follows is a list and brief description of the major opportunities.

Control of Excess Air.

The use of a greater amount of combustion air than is necessary can constitute a major energy waste. Certainly, the use of insufficient air is just as wasteful, but probably less common due to recent emphasis on air pollution problems, particularly visible smoke formation.

There is no accurate data on just how much excess air is used in the "average" furnace, or how much energy is wasted annually due to poor control of air/fuel ratios. And care should be taken in attempting to estimate the energy savings achievable through a reduction in excess air. For example, reducing the amount of combustion air, with no change in the rate at which fuel is fired, may result in a higher flame temperature and a more rapid heating of the work and a shorter, energy saving, cycle.

If in addition to reducing air flow, the fuel flow is also reduced, there will be a decreased gas velocity and less turbulence in the furnace, and an increased residence time of the hot gases within the combustion chamber. But the exact effect of these changes on heat transfer to the work and to the furnace walls, is not always evident or readily estimated. Therefore, in order to find out accurately the savings achieved, one must make a new heat balance.

In spite of these complexities, the control of excess air is probably the single most important item in energy conservation in furnaces. The determination of excess air by means of a flue gas analysis is essential, in any event, to the calculation of stack losses and the setting up of a heat balance.

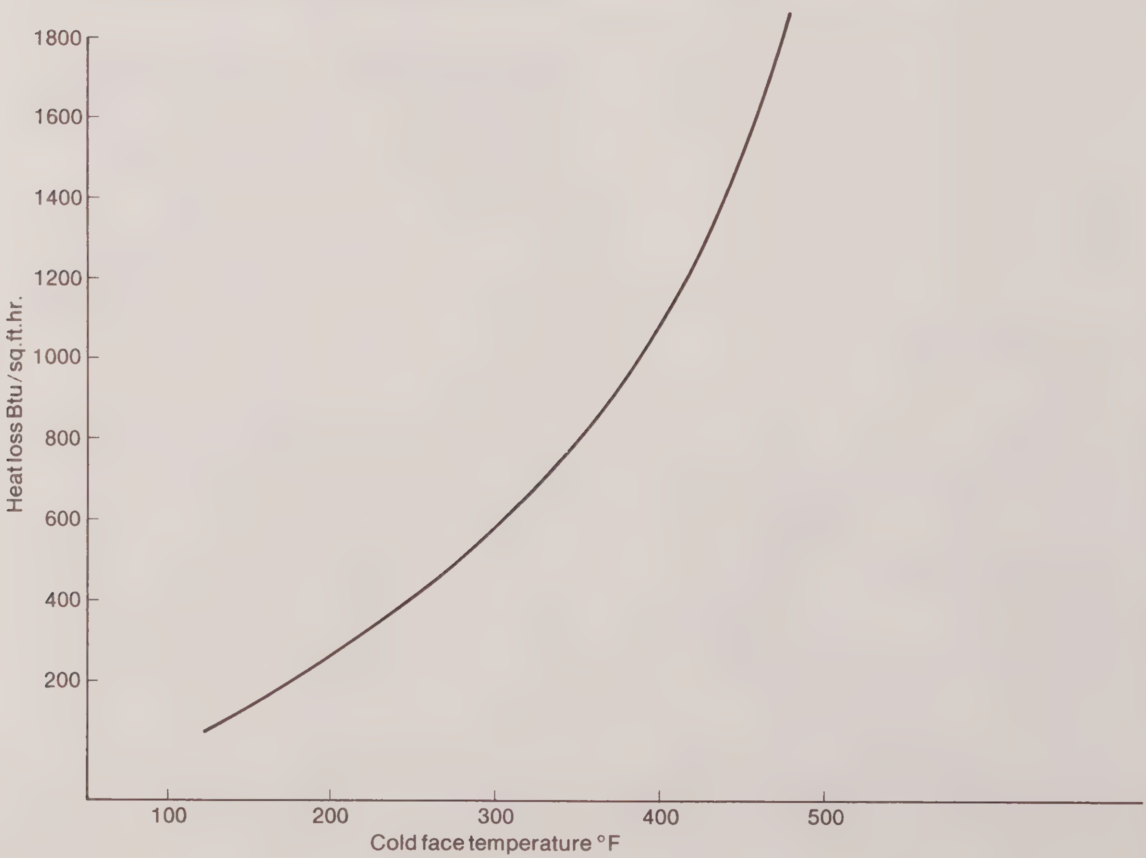
Recover Waste Heat.

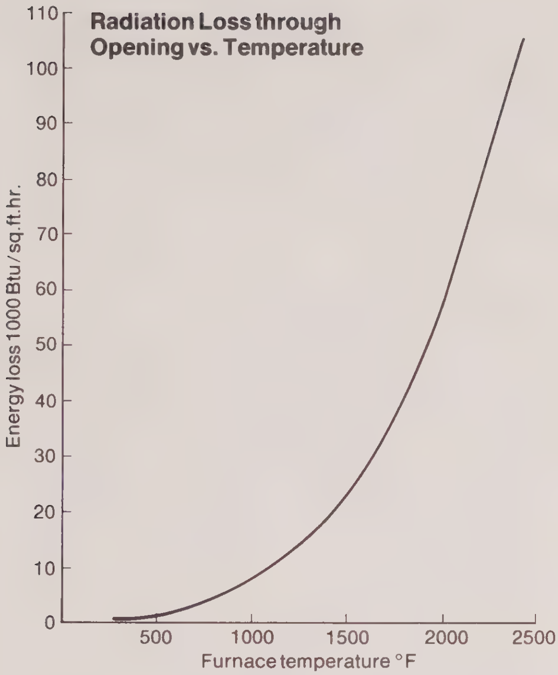
An industrial furnace, kiln, or oven almost inevitably exhausts gases at some temperature above the ambient, and hence contain useful energy which can be recovered. The uses to which recovered energy can be put are numerous. If the gas is at a high temperature, say 1500°F or higher, it can be used to generate steam and perform mechanical work or to generate electricity. Lower temperature gas streams have less value, but can be useful and save cost in such applications as drying and preheating incoming products, in heating water, or in space heating. If the stream is only a few degrees above the ambient temperature, it may still contain energy, but it may well be impossible to recover it economically.

If recoverable energy is not available on a regularly scheduled or continuous basis, it is usually best to try to return it to the same system that produced it. An example is the use of stack gas heat from an intermittently operated furnace to preheat the combustion air for the same furnace. In this application, waste heat still exists at a reasonably high temperature, and could be useful for space heating or for drying even if it had to be supplemented during furnace shut down by an auxiliary heater.

The "Process Design" book in this series contains much information on energy recovery techniques. Case histories of particular applications are found in a number of the booklets in this series (see the index in Booklet 1 for a complete list).

Heat Loss from Furnace Walls vs. Outside Wall Temperature





Insulation.

Furnace insulation that is inadequate or in poor condition can waste large amounts of energy, and usually in a form that is not readily recoverable. In fact, in one recorded case 20% of the fuel energy fired was still being lost through insulation after the obvious steps to conserve energy had been taken.

For an indication of the importance of the losses by measuring the temperature of the outside of furnace walls and roof. A temperature of 175-150°F indicates that the losses are in the reasonable range; a temperature of 500°F or higher means that the losses are probably quite large. An estimate of the energy loss per square foot per hour, as a function of outside wall temperature, is shown in the chart.

For a large installation, an infrared thermographic survey will measure accurately the temperature of large and complex areas. It will also serve to highlight hot spots, even quite small ones, caused by locally damaged insulation.

When installing new insulation or when retrofitting existing equipment, one should give serious consideration to ceramic fiber blankets instead of conventional fire brick. This material offers several distinct advantages:

- It has only one-third to one-half the heat conductivity of fire brick, and may be installed in correspondingly thinner layers for a given heat loss.
- It has a heat storage of about one-tenth that of an equivalent layer of insulating brick. This feature saves both energy and time in start-up, or in reheating during a batch cycling operation.
- It is immune to failures by spalling or cracking due to rapid heating and cooling.
- Its light weight makes it possible to install it without major rebuilding of a furnace.

It does, however, have some disadvantages:

- Since it is very low in physical strength, it cannot be installed on furnace floors or in other areas where it would be subjected to mechanical abrasion.
- Since its insulating properties depend on its high porosity, its use should be questioned in any service where the pores might be plugged up by condensing fumes or by particulate matter.
- It is intended for installation on the hot side of furnace walls or roofs. A blanket of fiber on the cold side of an existing furnace wall may cause some of the interior layers of brick to heat beyond their useful service temperature.

Openings and Leaks.

The mechanisms by which energy is wasted through open ports in a furnace or accidental leaks in the system can be classified as radiation losses, convective losses through the opening (exfiltration), or both.

Radiation is, of course, a line of sight phenomenon; if we can see the hot inside of the furnace, heat is being lost by radiation. The amount of heat loss is a linear function of the area of the opening and is proportional to the fourth power of the absolute temperature.

As a simplified example, a slot opening 6″ high by 8′ long in a 2200°F forging furnace will lose heat by radiation at a rate of 79,000 x (0.5 x 8) = 316,000 Btu/hr. This is in addition to any loss resulting from gases flowing through the opening.

Outward gas flow through a port or leak is generally not a major source of energy loss. If the leak is merely hot completely burned gas from

the furnace, it represents a small amount of exhaust gas which otherwise would have been wasted up the stack. If the outward leak results in long flames outside the furnace, it will represent a significant heat loss to the process. This could be eliminated by fixing the leak or optimizing the flame shape.

The infiltration of cold air into the furnace can, on the other hand, represent a serious energy loss. Every pound of excess cold air leaking into a 2200°F furnace represents a waste of 510 Btu. This infiltration commonly occurs because, in the absence of a well adjusted flue damper, there tends to be a slight vacuum near the bottom of the combustion chamber. Due to the "chimney effect", the pressure will be lowest at the furnace floor and will gradually rise to the local barometric pressure at the point where the stack exhausts to the atmosphere. The pressure difference, hence the volume of the air infiltrated and the amount of energy lost, depends on the furnace temperature, the height of the flue gas exit above the furnace floor, and the size of the opening through which cold air is entering.

The following table illustrates the relationship among these variables:

Heat Loss Due to Air Infiltration
Btu per hour per sq. in. of opening

Temp. °F	Height — Furnace Floor to Stack Exhaust 6′	8′	10′	12′	16′	20′
800	3600	4000	4800	5200	6100	6900
1200	5500	6900	7500	8100	9800	11000
1600	8200	10200	11200	12700	15200	17500
2000	10510	13200	14700	16500	18500	21300
2400	13500	16200	18100	20500	23200	25900

Thus, a slot opening 8 feet long by 6 inches high in a 2200°F forging furnace, with the stack exhaust located 12 feet above the furnace floor, would have the following heat loss due to air infiltration:

18,500 Btu/hr. sq. in. × (8 x 0.5) sq. ft. × 144 sq. in/sq. ft. = 10,600,000 Btu/hr.

This much energy is equivalent to 76 gal. (U.S.) of #2 fuel oil per hour. To prevent such an excessive loss, a damper or other constriction should be installed in the exhaust stack in order to increase the pressure in the combustion chamber to atmospheric or slightly higher. A frequent recommendation, even with openings or leaks much smaller than that described above, is to install an automatically controlled damper to maintain a positive pressure of 0.01 to 0.05 inches of water. Thus, if leaks do occur, they will be small outward leaks and will waste far less energy than cold air infiltration.

Shut Down Idle Equipment.

When heating equipment is out of service, either due to scheduled shut downs or to interruptions in production, energy can almost always be saved by allowing the equipment to cool down and reheating it later. If the shut-down time is short, it may be best to permit the equipment to cool to some intermediate temperature, to idle at this reduced temperature for a period, and then reheat to the operating temperature.

Unfortunately, there seems to be no good general law or rule-of-thumb as to when to shut down, when to idle at lowered temperature, and when to hold at operating temperature. The best decision depends not only on the projected down time, but most importantly on the characteristics of the specific piece of equipment under consideration. To reach a decision which will save the most energy, several bits of information are needed. They are:

1. The time for the equipment to cool, with burners off, to room temperature as well as to several intermediate temperatures.
2. The rate of fuel flow required to idle at operating temperatures and at each of the intermediate temperatures.
3. The time required to reheat from room temperature and from each of the intermediate points.
4. The total fuel required to reheat from each of the above temperatures.
5. The maximum rate of temperature change that will not result in equipment damage.

With this information, and a projected down time schedule, the cycle which uses the least fuel is easily determined.

In some cases the desired shut down and reheat cycle may incur some additional labour costs; in others, product or equipment may be damaged by excessive heating or cooling rates. These costs must, of course, be balanced against the savings in the cost of energy.

Schedule for Full Load Operations.

It is generally accepted that it is more efficient to operate heating equipment at its full design load rather than at some lower production rate. It is simple to translate this conventional wisdom to actual fuel usage and costs.

As an example, consider a continuous brazing furnace, fired at the rate of 5×10^6 Btu per hour, and a full load capacity of 100 units of product per hour. A heat balance shows that 1×10^6 Btu actually heats the product (10,000 Btu/unit), while the other 4×10^6 Btu goes to stack and other losses. This is a reasonably high energy efficiency for a heating treating operation.

If the required production rate is reduced to one-third of the furnace capacity, there are two general alternatives:

1. The furnace can be operated at 100 units per hour, but only operated every third day or third week. The fuel usage will be 5×10^6 Btu/hr., or 50,000 per unit of product, disregarding the energy required to reheat the furnace to working temperature.
2. The furnace can be operated every day with product fed at only 33 units per hour. Under these conditions, the furnace will still waste energy at the rate of 40 MM Btu/hr., and will deliver 330,000 Btu/hr. to the product. Total fuel usage will be 4,330,000 Btu/hr., or $\frac{4,330,000}{33} = 131,000$ Btu per unit.

The second alternative is probably the more convenient schedule in that it minimizes the problems of material handling, of storage space for a larger work-in-process inventory, and of poor worker morale that sometimes (not always!) results from frequent changes in job assignments. It also increases by 81,000 Btu the energy used per unit of product.

Alternative one, in spite of its scheduling inconvenience, is very attractive.

In some cases it may be desirable to increase the throughput of an existing furnace. If, in the previous example, it was decided to increase the production rate from 100 units per hour to 120 units it could conceivably be accomplished by speeding up the conveyor mechanism by 20%. Since, this would reduce the dwell time of the product in the furnace, it might be necessary to increase the heat transfer rate by raising the temperature of the furnace atmosphere; thus increasing the fuel consumption per hour. The higher temperature in the furnace would result in increases in stack loss and in the loss through furnace walls and roof. The increased volume of hot gas flowing would cause greater turbulence, which would increase both the heat transfer to the product and the loss through the walls.

The result of all of these conflicting changes is very difficult to estimate; it might be that the scheme is possible, but only at a sacrifice in efficiency, i.e., an increase in fuel used per unit of product. If the conveyor already has a variable speed drive, it might be possible to try the proposal and generate a new heat balance. If not, a discussion with the furnace manufacturer or a competent consultant is suggested before expensive and irreversible changes are made.

Minimize Energy Loss During Cycling.

When a batch furnace is opened to remove one load and put in another, it is obvious that large amounts of energy are lost through radiation and cold air infiltration as discussed earlier. The amount of this loss can be measured by a rather simple experiment:

1. Open the hot furnace and remove a batch of product as usual.
2. Reload any jigs or fixtures that are normally used — do not load any product. During these two steps, the furnace should be open for the length of time that is normal in production.
3. Close the furnace, and reheat to operating temperature.

The amount of fuel used during these steps is a direct measure of the energy lost due to cycling.

The major source of the wasted energy is the stored heat or sensible heat, in the hot furnace walls, floor, and roof. The loss mechanisms are both radiation and cold air infiltration through the open door(s). The normal heat loss by conduction through the furnace walls is usually small when compared to this "open door" loss. Another souce of wasted heat, usually less important, is the sensible heat of any jigs, fixtures, or carriers which must be heated and cooled during each cycle. These facts point to several techniques of conserving energy.

- Since the heat flow through open doors is a function of time, energy is saved by keeping the open-door time as short as possible. If, for example, one must wait 10 minutes for arrival

of the next batch of product to be treated, shut the door during the waiting period.

- Supporting jigs and fixtures should be designed for the minimum heat capacity. In general, this means designing to the minimum mass. Note that in terms of heat capacity per pound, most metals store only half as much heat as ceramics.
- The most important method of saving energy in a furnace which must be cycled is to use an insulating material which has a very low heat capacity per unit volume, such as ceramic fiber. The following analysis is based on data furnished by an insulation manufacturer.

A wall of insulating fire brick, designed for furnace temperature of 2000°F and a cold face at 200°F, would be about 12″ thick and would store 12,600 Btu/sq. ft. of sensible heat. In a furnace of 8′ x 6′ x 5′ inside dimensions, this amounts to a total storage of 2,970,000 Btu. If the furnace cooled to 1700°F during a batch change, the storage would be reduced to 2,510,000 Btu, or the energy loss would be 460,000 Btu.

Ceramic fiber insulation on the other hand, would be only 4.7″ thick and would store only 680 Btu/sq. ft. The total stored heat would be 733,000 Btu most of it in the brick floor, and the loss in cooling to 1700°F would be only 114,000 Btu. Assuming a stack loss of 45% during the re-heat period, the fuel saving due to ceramic fiber insulation is

$$\frac{(460{,}000-14{,}000)\text{ Btu}}{(1-0.45) \times 180{,}000\text{ Btu/gal}} = 4.5 \text{ gal. of fuel oil}$$

If the temperature dropped to 1500°F during cycling, the saving would be 7.2 gal. of oil.

For heating up from room temperature, the firebrick insulation would require 38.5 gal. of oil; the ceramic fiber design only 9.5 gal.

Miscellaneous Energy Conservation Opportunities.

There are many practices and procedures for furnaces, kilns and ovens that waste energy that often go unnoticed. This listing is not exhaustive, but covers some of the more important points:

- Over-specification by the parts designer is sometimes due to an early desire for a large factor of safety, to a reluctance to change something that is working, or to a lack of appreciation of the present cost of energy and its probably future increase. Examples include such things as a carburized case of 0.040 when 0.020 is adequate, or a drying and baking schedule on a painted part of one hour when 20 minutes is long enough. Design engineers will usually welcome cost saving suggestions, particularly if the credit is shared.
- Production people are guilty of a similar energy waste when they extend an annealing cycle 2 hours longer than is necessary or when they start heating up a cold furnace earlier than need be because it's more convenient. Education and an energy conscious approach are needed.
- Protective gas atmospheres which are allowed to flow at a greater rate than is essential are wasting energy, both in the mass of gas which must be heated in the furnace, and in the fuel value of the protective gas used.
- Massive jigs, carriers, or fixtures which must be heated and cooled with each batch, or with each trip through a continuous furnace, constitute a built-in energy waste. Such jigs should be as low in weight as possible; in some cases they can be completely eliminated.
- Water cooled rails, supports, door parts, etc., waste energy with every gallon of warm water that is sent to the drain. They can often be replaced with parts made of heat resistant alloys or ceramics, or the heat in the hot water may be recoverable.
- Scaling problems have sometimes been controlled by using expensive alloys when the same result might have been achieved by adjusting the excess air to keep the furnace atmosphere down to 1 or 2% oxygen. The latter course saves energy, both in the heat treating furnace and in the alloy preparation.

Continuous Efficiency Monitoring.

The most efficient of furnaces can drift from its optimum adjustments unless it is monitored on a regular basis.

The most important monitoring instrument is a fuel usage meter, preferably one for each major piece of fuel using equipment, read at least weekly and preferably at the beginning and end of each shift. A graph or a tabulation of fuel consumption per unit of production will soon show changes in equipment or in production practices which affect energy efficiency adversely. Just as important, such monitoring will measure the efficiency of an energy conservation project.

Fuel monitoring is, or course, the bottom line measurement for energy efficiency, but it has its limitations. It can detect some of the causes of possible energy waste, particularly those that have to do with scheduling changes such as excessive idling, changes in batch size, changes in product design, etc. In the case of other possible causes for energy waste, such as a change in the amount of combustion air, fuel monitoring alone will disclose a change, but will give no clues as to the cause. For this reason, some additional monitoring is desirable.

A complete flue gas analysis is also a very useful tool for checking furnace efficiency and is suggested at regular intervals. Possible schedules might be set up for checking monthly, or even more frequently.

Continuous flue gas analyzers (oxygen) are recommended for any major combustion use. As well as being permanently recorded, readings should be noted hourly — along with other important parameters, particularly exit temperature. Any changes in readings should be examined and its cause (such as changes in excess air or infiltration, or even fuel quality) determined. The cost of an analyzer can be justified by the speed with which it can indicate trouble and save both fuel and production material.

An instrument for measuring flue gas temperature is often not installed, since it can be assumed that this temperature depends directly on the control temperature in the furnace. If, however, a recuperator or other waste heat recovery device is put in, temperature at the flue gas outlet from this heat exchanger should be measured. A change in this temperature, if not accompanied by a change in furnace temperature, would indicate that the heat exchanger is not operating properly and needs maintenance or repair.

No monitoring instrument can replace the need for a good preventative maintenance programme. The reverse is also true; the best of maintenance skills does not do the same job as instrumentation. To hold to a high level of energy management, both maintenance and monitoring are needed.

Methods of measurement for heat balances

Previously, it was pointed out that measurements of such factors as fuel usage rate, temperatures, flue gas analysis, etc., are necessary for estimating a heat balance and overall efficiency of a furnace, kiln or oven. A few basic suggestions on measurement are in order.

Measuring Fuel Consumption.

The ideal instrument for measuring the flow of gas or oil to a furnace is a positive displacement totalizing meter, of the type used by fuel vendors. If such a meter is read once an hour, or even once a shift, the hourly fuel rate is readily calculated for the furnace on which it is installed. It can easily be moved from one furnace to another, if appropriate pipe fittings and valves are installed in the fuel line to each furnace.

Flow indicators, such as orifice plate or a rotameter, are usually less expensive and may be adequate for measuring a flow rate that is steady over long periods of time. They are not satisfactory when the temperature control system is one which makes frequent large changes in the amount of fuel supplied. In such cases, a totalizing meter is essential. Flow indicators can be useful to assure that proper fuel distribution exists among the individual burners of a multi-burner installation. This requires, of course, an indicator installed on each individual burner.

Meters of any type should be sized for the job. For example, if a furnace uses 100 cfh of gas, a suitable meter should indicate amounts as small as 1 cubic foot. If, on the other hand, the usage is 10,000 cfh, a minimum indication of 100 cf is adequate.

Measuring Energy Input — Electric Furnaces.

Here the instantaneous flow rate of electrical energy can conveniently be measured with a clamp-on ammeter. This instrument will measure the current demand in amperes if *one* of the wires to the furnace is surrounded by the spring loaded C-clamp which is part of the instrument. The flow rate (power) in watts is simply amperes times the applied voltage, or if multiple heating elements are wired into a

3-phase network it is amperes times volts times the square root of three (1.732).

If the temperature control system is of the full on-off variety, you can measure energy by wiring an electric clock across the heater terminals to indicate the total turned-on time. For example, if after 8 hours of elapsed time the clock indicates 5.5 hours, and the heaters draw 15 kilowatts, the average energy usage rate is $15\ \text{Kw} \times \frac{5.5\text{h}}{8\text{h}} = 10.3$ Kw.

If the temperature is controlled by a throttling device, such as variable inductance transformers or silicon controlled rectifiers (SCR's) one must use a recording kilowatt hour meter of the type used by the electric utility companies.

Measuring Temperatures.

For the temperature range of concern in this handbook, a thermocouple is by far the most convenient and satisfactory device; thermometers, of either the bi-metallic or liquid filled variety, may sometimes be less expensive; however, they are limited to temperatures below about 800°F, and can be inconvenient to read if the required location of the measurement is in a spot that is difficult to reach.

When the temperature to be measured is that of furnace flue gas, the temperature should be measured as near as possible to the point at which the gases leave the combustion chamber. If the measurement is made after the gas has been cooled, either by wall losses from duct work or by the infiltration of cold air, the resulting heat balance will be erroneous. If the flue gas is fed from the combustion chamber to waste heat recovery gear, such a recuperator, a heat exchanger, or a waste heat boiler, temperature measurements, should be made both at the combustion chamber exit and at the exit from the heat recovery device. Both measurements are needed in order to be assured that the heat exchanger is continuing to operate properly.

Analyzing Flue Gas

As covered in the section of this booklet on boilers, the Orsat analyzer has long been considered the standard instrument for a flue gas analysis. It analyzes separately for the following gases, by volume.

- Carbon dioxide — an indicator of the amount of excess air.
- Carbon monoxide — in amounts more than about 0.1% is an indicator of incomplete combustion.
- Oxygen — is a general indicator of the amount of excess air — regardless of the fuel used.
- Nitrogen — is not analyzed directly, but is assumed to be the remainder of the sample.

Water is condensed during the sample preparation. Its amount in the hot gas can be estimated from the amount of excess air and a knowledge of the type of fuel used.

A simpler, less costly device than the Orsat measures only CO_2 by chemical absorption and is commonly used by servicemen in adjusting domestic furnaces. It should be used as a guide but not considered absolutely accurate.

Several electronic instruments can be installed to continuously monitor flue gas. Infrared units to measure carbon dioxide or paramanetic or zirconium oxide units to measure oxygen yield accurate and permanent records of changes in combustion conditions. Where fuel type or composition may change, the oxygen type of analyzer is preferable to the CO_2 unit.

For controlling burner performance, samples should be taken as close to the burner as possible if infiltration is believed to occur. Further measurements downstream can show leaky settings, where heat loss occurs.

Measuring Gas Flows at Low Pressures.

If the amount of excess air in a furnace or oven must be more than about 200%, the use of an Orsat analysis to calculate mass flow rate and stack loss becomes very inaccurate. One must resort, therefore, to direct measurement of the gas flows either at the air intake, in the stack, or some other convenient point in the system.

Flow meters all cause some slight drop in pressure of the flowing fluid and are not suitable for use in the combustion system, where pressure is typically only 1 to 4 inches of water. The choice of instruments, then, is rather limited.

The pitot tube actually consists of two tubes, one with an opening facing into the flow. The difference in pressure between the two tubes is an indication of gas velocity. Pitot tubes may be used in ducts 4″ in diameter or larger, over a quite wide range of gas velocities, and at temperatures limited only by the materials for tube construction. For best accuracy, there should be 10 diameters or more of straight duct before and after the pitot tube.

A hot wire anemometer indicates gas velocity by measuring the cooling effect of a gas stream on an electrically heated wire. They are available as either fixed or portable instruments. They are limited in the temperature at which they can operate; 250°F is a normal upper limitation.

Mechanical anemometers utilize a fan or a turbine whose rotational speed is a function of the velocity of the driving fluid. Depending on application, e.g., hand held for room air velocity measurement or models for permanent installation in a pipeline, their cost and complexity vary widely. They are, for mechanical reasons, usually confined to temperature ranges below about 200°F.

In general, all of these devices are subject to major errors if they are allowed to collect gummy materials or particulate matter. Under such conditions one must clean the instruments quite frequently, or depend on the Orsat analysis and calculate the gas flow rate.

Different types of Furnaces, Kilns, and Ovens

The principles of obtaining the measurements and performing the calculations for a heat balance are exactly the same for each type of industrial heating equipment. They are, of course, to identify and to measure or estimate all the quantities of energy entering and leaving the equipment. In this sense, the job is the same whether the equipment is called an electric box hardening furnace, a bell furnace, a brick kiln, or a continuous bakery oven. There are nonetheless detailed differences in the best approach to the job, depending on the specific type of equipment.

Direct fired furnaces.

Direct fired furnaces are those in which the products of combustion (the flue gas) come into direct contact with the product being heated. This category may be subdivided into batch and continuous furnaces.

Batch direct fired furnaces include the following commercial types.

Box furnaces.

Car bottom furnaces.

Pit furnaces.

Bell furnaces.

Rotary retort (some).

These furnaces may be further classified according to their intended use, such as brazing, drawing, hardening, forging, etc.

The example in an earlier section illustrates a heat balance on this type of furnace. Specific items to watch for — in addition to fuel air ratio, adequate insulation, and waste heat recovery — are listed below:

- Frequent opening and closing of the furnace often results in leaks around the gaskets or seals, and energy losses by cold air infiltration. This can be particularly important in the seals around the edges of a car bottom furnace. Regular inspection and maintenance is called for.

- Air infiltration through unavoidable leaks can be prevented, or minimized, by installing an automatically controlled flue damper to maintain a balanced pressure in the furnace chamber.

- An obvious source of energy loss with a batch furnace is the heat which escapes during the unloading and reloading period between batches. This loss may be measured by metering the fuel flow from the time the door is opened for unloading until it is closed on the new load and the next cycle started. While this loss was not treated in detail in the heat balance described earlier, it obviously must be considered in calculating overall fuel usage per unit of product.

- A single batch cycle will, of course, use less energy if the furnace walls are relatively hot when the cycle starts; hence, the door open time between batches should be held to the minimum.

Another type, the continuous direct fired furnace, is one in which product is fed into and removed from the furnace in either a continuous or intermittent fashion, i.e. there is no distinct batch.

Commercial designations include:
Belt furnaces.
Roller hearth furnaces.
Rotary hearth.
Shaker hearth
Slot (forging) furnaces.
Pusher furnaces.
Rotary retorts (some).
Rotary kilns, and others.

A heat balance for a continuous furnace is essentially the same as a batch furnace, however, there are some special considerations involved:

- Since there is no batch cycle time, measurements and calculations should be made on the basis of some specific time interval such as an hour or a shift. Ideally, heat balances should be made both at idling (no load) conditions, and at design (full load). Fuel use at partial loads can be estimated from these data.

- Since access ports for the charging and removal of product are open either all or most of the time, energy loss because of the openings is more important than in a batch furnace. A slight positive pressure in the furnace is recommended.

- Losses by radiation through open ports can be large, and might well be considered as a separate energy loss in the heat balance. It is obvious that such openings should be as small as is practical.

- In some continuous furnaces, the material handling gear (belt, rollers, etc.) is all within the hot zone. In others, however, a belt may leave the hot zone and return at room temperature. In such cases, the energy required to reheat the belt should be considered as a loss (energy output) in calculating the heat balance.

Indirect fired furnaces.

These are furnaces in which the combustion gases do not come into contact with the product. This may be merely to protect the product from the local over heating; it is more frequent to permit careful chemical control of the furnace atmosphere (e.g. oxidizing, reducing, neutral, carburizing, etc.).

These furnaces may be batch or continuous in operation; may be any of the mechanical designs listed under direct fired furnaces (box, pit, bell, roller hearth, etc.) and can be further broken down into:

- Muffle furnaces.
- (Controlled) atmosphere furnaces.
- Radiant tube furnaces.
- Carburizing furnaces.
- Carbonitriding furnaces.
- Salt pots.

Those various methods of categorizing can give rise to such labels as a "box type, radiant tube, controlled atmosphere, hardening furnace."

An indirectly fired furnace with atmospheric air in contact with the product can be treated in almost exactly the same way as an equivalent direct fired furnace from the point of view of a heat balance. There are two minor exceptions.

- If outside air is deliberately drawn through the product chamber, e.g. to cool the product before discharge from the furnace, the volume and the exit temperature of this air must be measured, and its heat content added to the output side of the heat balance.

- If air is not circulated through the product chamber, i.e. if the chamber is closed as well as possible, there will not be any tendency towards air infiltration as is the case in direct firing. It is unnecessary and undesirable to make any efforts to hold a positive pressure in the product chamber.

In a controlled atmosphere furnace the product chamber is flushed free of air with some special gas, and gas continues to flow during the firing cycle to maintain a slight positive pressure. The energy flows due this controlled atmosphere should be accounted for.

In calculating the heat balance one should

consider the gas generator as part of a single system along with the furnace itself, and treat the energy used by the generator per hour or per cycle as one of the energy inputs. Since only a very small percentage of the atmosphere will actually combine with the product, this same amount of energy should appear as a waste heat output.

The following list, indicates the method of calculating the heat content of different types of furnace atmospheres.

- For exothermic generator gas, the energy content should be considered as the heating value of the fuel furnished to the generator.
- For endothermic generator gas, the energy content is the fuel value of the gas charged, including that which is used for external heating of the generator tubes.
- Dissociated ammonia has a fuel value of 16,000 Btu/lb (490 Btu/cf), plus the energy used for external heating of the generator tubes.
- If any of the above gases are conditioned by the removal of water vapor and/or carbon dioxide, the energy for this conditioning must be added as part of the system input.
- Pure hydrogen has a heating value of 61,100 Btu/lb, or 325 Btu/cf.
- Nitrogen, liquid or in pressure tanks, has no heating value.
- Propane, used in preparing enriched gas, has a heating value of 22,000 Btu/lb., 91,000 Btu/gal, or 2500 Btu/cf.

The need to meter gas to an atmosphere generator is implied by the preceding. If a central generator is used to furnish the atmosphere gas for a group of furnaces, it may be adequate to meter material to the generator and estimate its allocation to the individual furnaces.

Special types of indirect fired furnaces.

a. Salt pots.

A salt pot — a fused salt bath — is a special type of a batch indirectly fired controlled atmosphere furnace. In calculating a heat balance, it may be treated like a direct fired batch furnace with, usually, a quite short cycle time. The single exception is the need to determine the amount of replacement salt charged per cycle, to calculate the energy needed to melt the salt and raise it to operating temperature, and to list this energy as a heat output.

The radiation loss from the open surface of a salt pot may be significant. It should be estimated and listed as an output in the heat balance.

b. Pack carburizing.

Pack, or box, carburizing is technically an indirect fired controlled atmosphere operation, which is usually performed in a batch type direct fired furnace. The heat required to heat up the carburizing box and all of its contents is part of the output in a heat balance. The fuel value of the carburizing material, charcoal for example, is added to the input side of the heat balance. If a portion of the charcoal is recovered for re-use, one need only consider the new charcoal added for each batch. To conserve energy, the tare weight of the box per pound of product, as well as the amount of carburizing material used, should be as low as is practicable.

c. Recirculating furnaces.

Recirculating fans or blowers act to mix or stir the furnace atmosphere. They promote a more uniform temperature, and at lower temperatures can increase the rate of heat transfer to the product. Since recirculation systems are designed to neither add or subtract energy from the furnaces, they can be generally ignored in calculating a heat balance. If portions of the recirculating system are outside of the heated zone, they can contribute to the energy losses due to radiation and convection. Outside ducts and fan housings should be well insulated.

Dryers.

Dryers can be defined as heating equipment, with the purpose of driving off a volatile material such as water or an organic solvent. They may be either batch or continuous in operation. The commercial name of a dryer will usually refer to the product being treated:
Paint drying oven.
Ceramic dryer.
Lumber kiln.
Continuous bakery oven.
Rotary retort parts dryer.
etc.

Dryers are usually operated at low temperature (150-500°F). However, in spite of this, heat

losses by radiation and convection from walls and ceiling can be very important, since the wall and ceiling areas tend to be rather large, and cycle times may be lengthy.

In addition, dryers are often operated with rather large quantities of excess air (200-1000%), in order to promote rapid drying and to prevent forming an explosive atmosphere if the solvent is combustible. If the excess air is above about 200%, a flue gas analysis becomes very inaccurate and direct measurement of air or flue gas flow rate must be used in order to calculate the stack loss. Obviously, the amount of excess air should be no greater than is required by the demands of the process.

Some further considerations with dryers:

- If the solvent being evaporated is combustible, the fuel value (heat of combustion) must be added to the input of the heat balance.
- Air pollution regulations require that hydrocarbons such as paint solvents be removed before any gas stream is exhausted to the atmosphere. This can be done by a variety of means, the most common one being to burn more fuel with the stack gas and raise its temperature to about 1600°F. Whatever the method, this clean up operation must be considered as an integral part of the system, and all the energy added at this point is an energy input to the heat balance.
- Drying systems commonly have very high stack losses because of the necessity of high percentages of excess air and the need to incinerate hydrocarbons vapors. Special attention should be given to the means of recovering this waste heat and if possible returning it to the system.
- Dryers are sometimes part of a more complex system. For example, in a continuous brick kiln-dryer combination there can be different zones: to dry out water, to increase the temperature slowly to the firing level, to fire the bricks, and to cool at a controlled rate. Bricks may be dried by hot air recovered from the cooling zone of the kiln.

To calculate a heat balance, the complex should be treated as a single system and only the energy and material flows which enter and leave it considered. If necessary, energy balances for a single part of the system such as the drying zone can then be estimated.

Electric furnaces.

Any of the types of furnaces, kilns, or ovens described up until now can be heated electrically instead of by directly burning fossil fuels. However, there are a few special items to consider in making a heat balance.

- Since there are no fuel combustion products, there is no stack loss in the usual sense. If the application is to a dryer or to a controlled atmosphere furnace, one must, of course, consider the energy flows associated with the drying air or with the special furnace atmosphere.
- A heat balance on an electric furnace, using a conversion factor of 3412 Btu/Kwh, will normally show a lower heat input than is required by an equivalent furnace fired by gas or oil. The high cost of electricity per Btu will frequently, however, out-weigh the apparent saving.
- To compare a gas or oil fired furnace with its electrical equivalent on the basis of fossil fuel burned instead of cost, a kilowatt hour should be valued at 10-12,000 Btu. This is the value of the fuel burned by a generating station to produce one kilowatt hour of electricity worth 3,412 Btu for furnace heating. The power plant loss is reflected, of course, in the cost of electricity.

Financial considerations.

The previous sections contain some suggestions for energy saving which will require the investment of capital dollars in order to achieve savings. In some cases, the savings per year may be so large, and the capital cost so small, that the desirability of the project is obvious. In other cases, a more detailed analysis is needed.

The Guidebook/Index discusses two of a number of procedures for making a financial analysis of your cost saving opportunities. An important factor in your analysis is the amount you are paying for your energy.

The reason for determining energy costs is to allow you to make valid analysis of the actions you might need to take to save energy and money. The cost varies widely with the fuel source used.

Industrial boilers

Among combustion devices, the industrial boiler is one of the largest consumers of energy. In fact, as a rough rule of thumb, 40 percent of total energy consumed in Canada is used by the industrial sector. Of this, roughly, 11 percent is used for direct heating — a full 16 percent goes into the production of steam. Obviously, improvements in boiler performance offer a real opportunity to reduce a significant proportion of fuel consumed on a national basis. But perhaps of greater interest in the short term, improvements in boiler performance generally spell substantial savings in operating costs for Canadian industry.

Getting Peak Performance.

The fundamental purpose of any industrial heating system is to convert the energy contained in the chemical bonds of the fuel into heat, and to transfer this heat into a working fluid such as steam, oil or air. The energy content of fuel is defined by its *heating value,* the number of British Thermal Units (Btu's) contained per unit weight or volume of the fuel. Combustion engineers generally make a distinction between the so-called "lower heating value" (LHV) and the "higher heating value" (HHV) of the fuel, the difference being the small amount of heat associated with the condensation of moisture in the flue gas. In boiler work, the HHV is the commonly used figure. Some typical HHV's for commonly used fuels are:

Natural Gas — 1,000 Btu/cu. ft.

Fuel Oil
No. 2 — 166,000 Btu/gal.
No. 6 — 180,000 Btu/gal.

Coal
Bituminous — 14,000 Btu/lb.
Sub-bituminous — 10,500 Btu/lb.
Lignite — 7,500 Btu/lb.

Again, the lowest grade fuel possible should be used whenever possible, to conserve premium fuel for those applications where they can be used most efficiently.

In the furnace, fuel is mixed with air and ignited, causing carbon, hydrogen, and sulfur in the fuel to oxidize rapidly and liberate chemical bonding energy. A precise amount of air is required to insure that there will be an oxygen molecule available for every combustible molecule. This precise amount is known as the *100% theoretical air, theoretical air or stoichiometric air*. If less than the theoretically required air is introduced into the furnace, there will be insufficient oxygen available, and some of the combustible material will go up the stack, paid for but unused. If more than the theoretical air is supplied (which is almost always done in actual practice, for reasons which will be discussed later) the furnace is said to be operating with *excess air*, usually expressed as a percentage of theoretical air. For example, a gas-fired package boiler may operate with about 35% excess air, or 1.35 times the theoretically required amount.

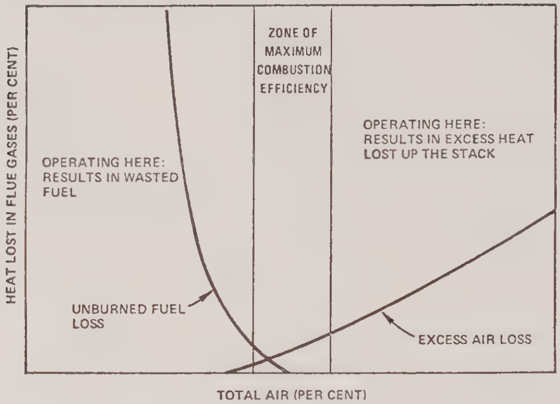
The mixture of gases which results from combustion of the fuel, consisting primarily of carbon dioxide, water vapor, nitrogen, and oxygen, makes up the *flue gas*. While some of the heat produced by the combustion reaction is transferred directly to the steam or process fluid by the radiation from the luminous flame in the furnace, a substantial amount of heat remains in the flue gas as it flows through the boiler. As the hot gas rises through the stack, heat is further extracted from it as it passes over banks of tubes placed in the gas path. These tube banks, known as *transfer* heater sections, are the important type to consider when retrofitting an existing boiler with heat recovery equipment.

Ultimately, of course, the objective is to get the heat into a working fluid which can be used in the process. The degree of success toward this goal is measured as *boiler (or heater) efficiency.* Boiler efficiency is calculated by dividing the quantity of heat transferred into the working fluid by the chemical heat content of the fuel entering the system. Boiler efficiency is the number we are most interested in, because it represents useful energy produced compared to theoretically available energy. In the sections which follow, this will be referred to simply as "boiler efficiency", although it will be understood that this could apply equally to process heaters in which the working fluid is other than water.

Parameters Affecting Boiler Performance.

Numerous operating and design variables have a substantial effect on boiler efficiency. It is important that each of these influences be

Effect of Combustion Air on Boiler Performance



understood, so that alternative measures which may be taken to improve the efficiency may be considered.

Fuel Characteristics: The properties of the fuel used in the boiler or heater exert a major influence on efficiency. To achieve proper combustion, the fuel must be well mixed with the combustion air. Mixing is a complicated phenomenon, particularly when liquid or solid fuels are used. When fuel oil is burned, it must be atomized to produce tiny droplets with a large surface area exposed to the air. The density, viscosity, and surface tension of the oil are all important determinants in the atomization and mixing process. Since these factors are greatly affected by temperature, it is necessary to maintain the fuel at the temperature for which the burner was designed. This is especially important when using heavy residual fuels (e.g., No. 6 fuel oil).

Another important property is the fuel heating value. This property is determined by the fuel's chemical composition and its water content.

Excess Air: The amount of excess air used in combustion is a crucial variable affecting boiler efficiency. The chart shows why. As pointed out earlier, a certain minimum amount of air is required to provide adequate oxygen to react with all the combustible components of the fuel. In practice, it is always necessary to provide somewhat more than the theoretical requirement, since the mixing process is never perfect and some of the oxygen brought in for combustion will not come into contact with molecules of combustible components. If too little air is supplied, some of the combustible material goes up the stack unburned. Large amounts of unburned combustible can result in a significant heat loss, although this condition rarely occurs. More commonly, the excess air significantly exceeds the required value and large amounts of heat are lost up the stack. Every attempt should be made to operate at the lowest excess air level possible, for efficiency. In essence, combustion control is aimed at effectively "walking the tightrope" between too much air and not enough.

Stack Gas Temperature: Because it represents a measure of the unrecoverable heat being wasted to the atmosphere, the temperature of the flue gases going up the stack is an important determinant of boiler efficiency. In considering installation of heat recovery equipment, you should remember that the flue gas temperature — less about 50°F — indicates a maximum to which a fluid can be heated. Its current value will, therefore, dictate possible applications for the recovered heat. Corrosion considerations do, however, set lower limits on the desirable value of the stack gas temperature. If fuel oil is used as fuel it is especially important to maintain a sufficient stack gas temperature to avoid condensation of water and sulphuric acid vapors on heater and chimney surfaces.

Steam or Process Fluid Conditions: The temperature, pressure, and rate of flow of the working fluid being heated reflect the all-important output of a boiler or process heater. They are, therefore, vital elements in determining the boiler's efficiency. In additon to indicating the state of boiler performance, variations in these quantities may, themselves, cause changes in the efficiency. For example, the rate of heat transfer from flue gas at a given temperature to steam flowing in a pipe will, in part, be determined by the velocity of the steam flow. Similarly, the temperature of the steam (and, by association, its pressure) will affect the heat transfer rate. Thus, for a given design, the boiler may have a different efficiency at one load level than at another. This affect is less pronounced when heat is transferred to a liquid (such as in a feedwater heater) than when it is transferred to a gas such as steam or air.

All of these parameters are interrelated through the complex processes of combustion and heat transfer which take place in a boiler or heater.

For example, improper fuel conditions require additional air for complete combustion. This excessive amount of air would, in turn, be reflected in an increase in stack gas temperature, as the increased velocity of the flue gases would generally cause them to pass over the heat transfer surfaces too fast to give up much of their heat content. Accompanying these changes would be a decrease in the rate of steam or process fluid available from the system.

A precise determination of boiler efficiency requires a detailed knowledge of fuel composition, atmospheric conditions, radiation losses from external furnace walls, and other data that are difficult to obtain in the average industrial installation. Flow-rates, temperatures, and pressures of fuel, steam, flue gas, combustion air, feedwater, and blowdown can be measured and an overall energy balance carried out to determine the boiler efficiency directly. However, an estimate, accurate within a few percent, can easily be made with a minimum of measured data by assuming some typical values for the fuel and air properties. This simple procedure uses the "Btu method" for combustion analysis, in which all quantities are referred to 10,000 Btu of heat content in the fuel input. Properties of a typical heavy fuel oil (about a No. 4) and a typical natural gas are used in the calculations.

The table on the next page outlines the step-by-step procedure. Step 1 lists the two required inputs — the percent of excess air and the flue gas exhaust temperature. These values are determined from measurements, as will be described later. In steps 2 through 7, the quantities of fuel, air, and moisture associated with 10,000 Btu of input heat are calculated. These quantities are used to determine the various heat losses attributable to the flue gas in Steps 8 through 10. Miscellaneous losses and the boiler efficiency are determined in Steps 11 and 12.

Boiler Efficiency Calculation Procedure

In general, the quickest and most accurate procedure to measure boiler efficiency is indirectly, *by the heat loss method.* Five measurements or inputs are required: the CO_2 or O_2 level (excess air), the stack temperature, the combustion air temperature, and the rated and actual boiler outputs. Two distinct losses occur. The first, dry flue gas loss (DFG) represents the sensible heat in the gases lost up the stack. The second, the hydrogen loss, is due to moisture in the flue gas formed from the combustion of hydrogen in the fuel. DFG depends on excess air and the difference in temperature between the flue gases and the combustion air. For a particular fuel, the hydrogen loss depends only on stack temperature and combustion air temperature.

In order to facilitate these calculations, graphical displays of the two heat losses are presented in the appendix to this booklet for three typical fuels: No. 6 and No. 2 fuel oils and natural gas. Another general chart appearing on the next page, enables the determination of the radiation loss for almost all boiler configurations. For a more detailed calculation of boiler performance, see the ASME Power Test Code for steam generating units.

Measurements — an Essential Ingredient.

As pointed out in the previous section, certain measurements are necessary to keep track of the performance of a boiler.

The most basic of these is the stack gas temperature. Though not adequate by itself to calculate the boiler efficiency, it does provide a running indicator of boiler performance; serious malfunctions will almost always show up instantly in the stack gas temperature. If the exhaust stack is accessible and visible from the operating area, the simplest way to measure stack temperature is with a dial-type thermometer. These are rugged and reliable devices which can be permanently installed directly in the stack. Some caution, however, must be exercised in using the indicated temperature for calculating the boiler efficiency, since there may be substantial variations in temperature across the stack and, in some installations, the thermometer may be subject to large errors due to radiation. A thermometer should be used which has an element long enough to extend well into the gas stream.

A continuous record of stack temperature may be obtained with a thermocouple (or other

Eight Steps to knowing your Boiler's Efficiency

1. Determine excess air from measured O_2 or CO_2.
2. Determine the difference between stack temperature and combustion air temperature (ΔT).
3. Determine sensible heat loss (any flue gas loss) using charts in the appendix to this booklet. (Intercept of ΔT line with excess air level.)
4. Determine loss due to hydrogen in fuel using charts in the appendix (intercept of the stack temperature and combustion air temperature lines).
5. Determine radiation loss from boiler casing using ABMA chart in the appendix, by following the boiler design load curve to where it meets operating load, then across to the vertical axis and down for water walls.
6. Add an estimate for unmeasured losses — 0.25 for natural gas, 0.50 for oil and 1.0 for coal.
7. Sum the losses 3→6.
8. Boiler efficiency – (100-losses)%.

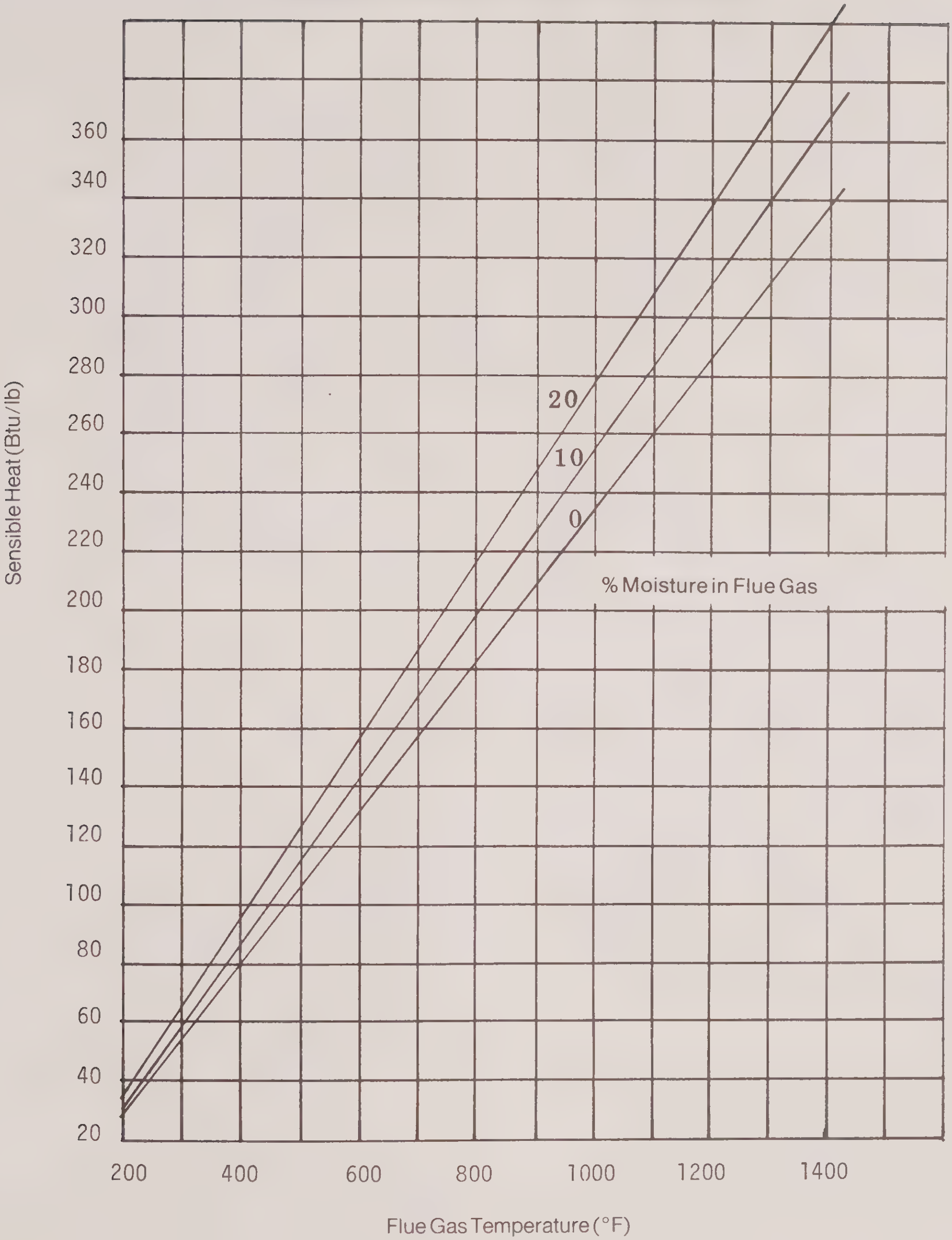
Example of Boiler Efficiency Calculations

The situation: A four waterwalled boiler rated at 30,000 lbs of steam per hour fires No. 2 or No. 6 oil or natural gas. At one third load (10,000 lbs.), the following measurements were taken for each fuel:

Fuel	Stack temp °F	Comb. air temp °F	O_2 (%)
No. 2 oil	600	100	7
No. 6 oil	600	100	7
Natural gas	550	100	7

Efficiency determination	No. 2	No. 6	Natural gas
1. Excess air (%)	45	45	45
2. Temperature diff. between stack and comb. air (°F)	500	500	450
3. Dry flue gas loss (sensible heat loss) (%)	13	13.2	11
4. Hydrogen loss (%)	6.7	6.9	11.6
5. Radiation loss (%)	2.6	2.6	2.6
6. Unmeasured losses (%)	.5	.5	.25
7. Total losses (%)	22.8	23.2	25.5
8. Efficiency (%)	77.2	76.8	74.5

Sensible Heat Content of Flue Gas



sensing element) and an electronic recorder. Also available are recorders which utilize mechanical temperature sensing elements. The same precautions mentioned earlier regarding dial-type thermometers must be exercised in the installation of these devices.

An overall measure of boiler efficiency can be made by direct or indirect measurement of fuel and steam flow rates. Simple orifice-type flow meters can be installed directly in natural gas and steam lines, and the total flow over a period of time determined. If the steam conditions and

the fuel heating value are known, the boiler efficiency can easily be calculated. A similar measurement, although made indirectly, can be obtained with a ratio-type boiler meter. With this device, steam flow is measured by use of an orifice in the steam line, while the fuel flow is inferred from a measurement of the pressure drop of the flue gas as it passes through the boiler. To interpret these readings, you must calibrate the boiler with the device in place. Once the calibration is made, the ratio-type boiler meter may be used to continuously adjust the steam and air flows to some predetermined ratio which has been found, through tests, to give efficient combustion.

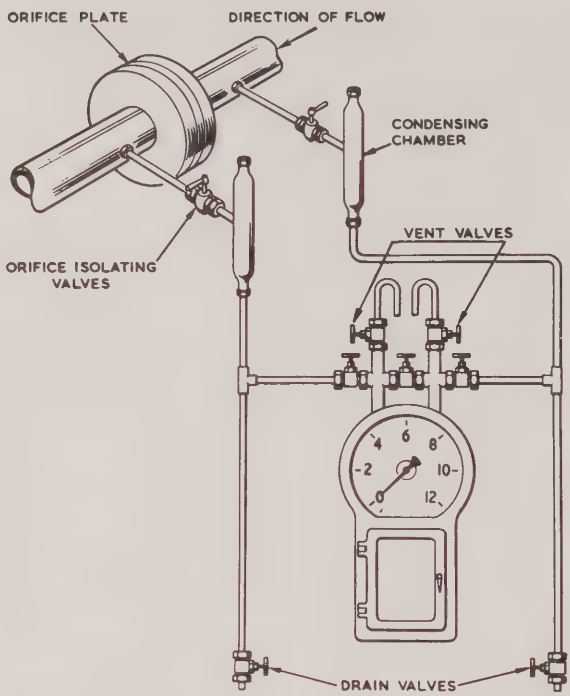
Perhaps the most accurate means of determining the state of combustion in a boiler or heater is the direct measurement of the chemical composition of the flue gas — in particular, the amount of oxygen and combustible components in the exhaust stack.

A low cost device, though the "messiest" method for determining gas composition, is an Orsat analyzer. Here, a sample of flue gas is drawn from the stack through a suitable sampling tube and bubbled successively through a series of pipettes, each of which contains a different chemical solution. Each of these solutions selectively absorbs one of the flue gas components, such as oxygen, carbon monoxide, or carbon dioxide. The reduction in volume of the sample as each gas is successively absorbed can be related to the quantity of the particular constituent that was present in the sample. With these quantities known, the percent of excess air used for combustion can be calculated.

Orsat analyzers are inexpensive, accurate enough for routine operational tests, and reasonably trouble-free. Maintenance personnel can easily be trained to use the apparatus. However, fresh reagents must be purchased or mixed every few weeks, and some calculation is necessary to convert the readings. Other devices are also available to give comparably accurate readings.

Portable combustion analyzers are easier and faster to use, and provide a direct reading of the percentage of oxygen or carbon dioxide in the flue gas sample. The sample is drawn continuously with a small pump housed in the analyzer case, through a filter which removes

Orifice Flow Meter with Mechanical Indicator



soot and other particulates and through a water trap.

The most satisfactory oxygen analyzers are either paramagnetic or zirconium oxide types. However, an equally accurate measurement — providing the fuel composition is relatively constant or known — can be made with an infrared carbon dioxide analyzer. Portable combustion analyzers may cost more but the investment can be a worthwhile one.

For larger installations, it may be desirable to provide a continuous record or at least a continuous indication of oxygen and combustibles in the flue gas. Systems for continuous monitoring the stack gas components generally run several thousand dollars, but they can often pay for themselves in a short time when used to provide continuous combustion control of the system. If several boilers or heaters are in operation simultaneously, it is possible to utilize a multipoint system which draws gas samples sequentially from several remote points. By

sharing the expensive sensors and electronic equipment, the incremental cost per boiler is reduced considerably.

A regular flue gas monitoring program is a vital first element in improving the performance of boilers and process heaters. The devices described above, used with proper care, can provide the necessary information to properly adjust air dampers for correct combustion conditions. Of course, proper sealing and cleaning of sampling lines and filters must be maintained to insure the validity of readings. As will be discussed later, continuous stack gas monitoring systems are also important elements in some automatic boiler control systems.

Boiler performance can usually be improved through several means, often with substantial economic return. Improvements may be brought about by improved maintenance and boiler operation, improved controls, new burners, tightening boiler settings and installation of heat recovery equipment.

Maintenance and Operation.

The key to all improvements in boiler operation and maintenance is frequent determination of boiler performance by use of heat loss methods described previously. If several boilers are brought on line as needed, clearly the most obvious first step would be to sequence the use of each boiler in order of decreasing boiler efficiency; thus, at reduced load, only the most efficient boiler would be used, and less efficient units would be brought on line as required. Since boilers are generally designed for optimum performance near full load, better overall efficiency will be obtained with two boilers operating at full capacity than with three operating at part load.

Keeping heat transfer surfaces clean is another important consideration in maintaining peak performance in boilers. The accumulation of scale on the water side of boiler tubes, and the accumulation of soot and ash on the gas side, introduce resistance to the flow of heat from the gas to the water. This additional resistance is reflected in higher stack-gas temperatures and in additional fuel required to generate a given amount of steam.

Scale build-up on the water side is the result of precipitation of minerals, particularly iron salts and silica, at high temperatures. These build-ups can be very costly; for example, a one thirty-second inch layer of scale, high in iron and silica, can reduce boiler efficiency by five to seven percent. This can be worth literally thousands of dollars per year in increased fuel consumption. Boiler deposits can be controlled by proper water conditioning. The services of a water conditioning specialist should be employed to obtain an analysis of the chemical content of boiler feedwater and to make recommendations on systems to condition it for prevention of scaling. Or, if done on a routine basis, tubes may be cleaned mechanically. But the cost of this option in boiler down-time can be prohibitive.

Soot build-up on the gas side is a serious problem in oil-fired equipment, and should not be ignored even in "dual fuel" gas-fired boilers. Performance of boilers temporarily fired with oil can be seriously degraded in a short time, since the heat transfer surfaces are not optimally designed for operation with sooty fuels. Soot may be remove by manual cleaning, but if oil is fired on a regular basis, a better solution to the problem is the installation of soot blowers in the boiler. These devices periodically inject blasts of compressed air or steam against tube surfaces and blow off soot deposits.

As an example of the kind of gain realizable with soot blowers, one company installed soot blowers on their two fire-tube boilers, rated at 400 and 500 horsepower respectively. The use of the blowers resulted in a 7.5 percent net reduction in fuel consumption, using No. 6 fuel oil. At a fuel cost of 35¢ per gallon (U.S.), the company repaid its capital investment in about 14 months.

Improving Boiler Controls.

As pointed out in an earlier section, proper control of combustion processes involves striking a satisfactory compromise between inadequate and excess air. Most small package boilers are usually fitted with a simple mechanical control system, commonly called a "jackshaft" controller. In this system, the steam pressure is sensed as the basic control signal. This signal regulates a mechanical linkage attached to the fuel valve and combustion air dampers. The relative motion of the two elements can be adjusted somewhat through the use of special cams, but because of the mechanical linkage arrangement, it is not

possible on a routine basis to adjust the relative air and fuel flow rates manually. The "jackshaft" system is usually set for a particular operating condition when the boiler is first installed, and adjustments are made only infrequently thereafter. Because the system must accommodate variations in the heating value of the fuel and in the air conditions, it is always set to provide a high value of excess air, that is, to be conservative with air so as to prevent any fuels from entering the region of unburned combustibles. Typically, for a gas fired package boiler, this setting is around 30 to 40% excess air.

An improvement on this basic system is the so-called "parallel positioning" control system. In this system, steam pressure is again the driving signal, but the mechanical linkage is replaced by a parallel set of pneumatic or electronic drivers. These drivers actuate the fuel and air controls in a preset pattern. With parallel positioning, some operator control is usually provided. If some means of flue gas analysis is provided, improvement in performance over the simple jackshaft system can usually be obtained.

A third and yet more sophisticated form of control is known as "pressure balancing." In this system, the fuel pressure at the burner and the pressure drop of the flue gas through the furnace are sensed directly, and the system is controlled to proportion these pressures. The success of this system in maintaining accurate combustion control rests on the assumption that the flow rates of fuel and air are directly related to these pressures. While this is true in part, the flows also depend on certain other variables, such as fuel and air temperature. Furthermore, since the fuel heating value may vary somewhat, the mass flow rate indicated by the burner pressure is not a totally accurate indicator of the amount of air required for proper combustion. While this system is one step closer to a true fuel and air metering system, it must still control toward the conservative side. It is the most common system in larger plants.

The most sophisticated of the basic systems generally available utilizes direct measurement of the fuel and air flow rates by the installation of flow metering devices in the fuel and air systems. The fuel and air flow rate signals are sent to an electronic computing device, which then controls the fuel valve and air dampers in a pre-programmed manner. Refinements on this system include cross-limiting, which prevents fuel and air from exceeding preset limits relative to one another, and oxygen feedback, in which an oxygen sensor installed in the stack feeds an additional control signal to the computing device to be included in the control computation.

The chart shows the typical reduction in the amount of excess air which can be obtained using the various types of control systems described above. This table also shows installed costs for the various types of control systems, as estimated by one manufacturer in mid-1974. While these costs are in U.S. dollars and would be somewhat higher today, they are reasonably accurate relative to one another.

Graphs in the appendix to this book may be used to estimate the percentage savings that can be realized by a reduction in excess air to 10 percent for natural gas and 20 percent for No. 6 fuel oil.

For natural gas, suppose the existing system operates at 40% excess air and a stack temperature of 600°F. Combustion air temperature is 75°F. Entering the figure at the intersection of 40% air and 525°F stack differential, the heat loss is 12.4 percent. At 10 percent excess air, the heat loss has been reduced to 9.5 percent. The gain in efficiency is a full 2.9% for a fuel saving of nearly 4 percent.

Similarly for oil, with the same temperature conditions (but originally at 60% excess air), the original heat loss would be 15.2 percent — reduced to 11.4% at 20 percent excess air. This gives an efficiency gain of 3.8% and a fuel gain of 5%.

Based on this knowledge, installation of boiler controls can be seen to pay for itself within one to two years. In fact, reducing excess air also reduces stack temperature and further savings will result.

Boiler Heat Recovery Equipment.

Once proper combustion is maintained in the boiler or process heater, further improvements in performance must be obtained by recouping some of the losses inherent in the basic design of the equipment. Some older units are poorly insulated, particularly over endplates and access doors of packaged boilers. Improving this situation is quite simple and inexpensive, and may account for several percent improvement in fuel consumption.

Another measure which can be employed in older fire-tube boilers having high stack gas temperatures is the installation of turbulence promoters (sometimes called turbulators) to enhance the rate of heat transfer in the tubes. These are simply twisted strips of high melting point metal which are inserted in each tube to create swirl and turbulence in the hot gases flowing inside the tubes. These devices cost very little per tube; their installation can improve boiler efficiency by several percent.

In addition to these "quick fixes", substantial gains in performance can be obtained through the installation of heat recovery surfaces in the flue gas path — a subject dealt with in both the "Furnaces, kilns and ovens" section of this booklet and in the "Process design and heat recovery" booklet in this series. (See index in Book I.)

In years past, the low cost of fuel made it uneconomical to add sufficient heat transfer surfaces to the boiler to bring stack gas temperatures much below 500 or 600°F. At today's prices, the capital investment required to add heat recovery surface can usually be repaid in a year or two through fuel savings. The heat recovered may be utilized in a number of ways, depending on the maximum temperature available from the flue gases.

If stack gas temperatures are several hundred degrees above the required steam temperature, it may be feasible to generate additional steam in

Fuel Savings Comparison of Boiler Combustion Control Systems

System Type	Btu Input Thous. Btu/Hr.	1974 Installed Cost $	Total Savings $/Yr	
			1.00/MBTU	2.00/MBTU
a) Jackshaft	10,000 25,000 50,000	18,000 18,500 19,000	0 0 0	0 0 0
b) Parallel (Operator Trim)	10,000 25,000 50,000	20,000 20,500 21,000	800 2,000 4,000	1,600 4,000 8,000
c) Pressure balancing	10,000 25,000 50,000	23,600 24,100 24,600	1,600 4,500 9,000	3,200 9,000 18,000
d) Metering (cross-limited)	10,000 25,000 50,000	28,600 29,100 29,600	3,500 8,750 17,500	7,000 17,500 35,000
e) Metering (cross-limited w/ 0_2 correction)	10,000 25,000 50,000	34,100 34,600 35,100	4,100 10,250 20,500	8,200 20,500 41,000

1. % Fuel Saving Capability (600°F Flue Gas Temp.)

(a) Jackshaft	– 0% (Base)	(43% Excess Air)
(b) Parallel positioning	–1.0%	(37% Excess Air)
(c) Pressure balancing	–2.0%	(31% Excess Air)
(d) Metering w/ cross-limiting	–4.3%	(15% Excess Air)
(e) Metering w/ cross-limiting & 0_2 feedback	–5.1%	(10% Excess Air)

2. Installed Cost vs. S/Yr. Fuel Savings (8000 Hr./Yr. Operation) Fuel Costs 1.00/MBTU and 2.00/MBTU.

a waste heat boiler, using either natural or forced circulation. At somewhat lower stack temperatures, an "economizer" can be used to preheat the feedwater nearly to the boiling point before it enters the boiling section.

Other process fluids can also be heated in a waste heat recovery unit in addition to, or instead of, the boiler water itself. For example, it might prove economically advantageous to replace steam tracing lines on pipes or storage tanks with lines using an organic heat transfer fluid heated in a heat recovery unit. Other substances used in the process, such as raw materials, may also be preheated to reduce the fuel energy required to bring them to the necessary processing temperature. After the flue gas temperature has been reduced to within about 50°F of the incoming feedwater temperature, it may be used to preheat incoming combustion air.

Generally speaking, the lower limit practicality for flue gas temperatures is around 200°F for natural gas-fired equipment, and 300 to 350°F for oil-fired boilers. The latter are limited by the necessity to avoid condensation of sulfuric acid vapors in the combustion products of sulfur bearing fuels.

Types of available heat recovery devices are discussed at length in the "Process Design" booklet; but as an example of the performance improvement obtainable with a flue gas heat recovery unit, consider the case of a small 500 horsepower package boiler operating with a 625°F stack temperature. The boiler feedwater enters at 212°F. Using an economizer to preheat the water to 300 degrees F seems to be the best thing to do. But, a finned tube economizer to accomplish this purpose costs about $8,000 at the factory, or about $12,000 installed. The unit recovers about 1.5 million Btu per hour, which, at a gas cost of $2.00 per Mcf, saves about $3.00 per operating hour. The investment would pay for itself in a typical operation in under three years.

Pay-back periods for air preheaters are usually somewhat longer, due to the higher capital investment required for these units, but with fuel prices rising they still represent an attractive investment opportunity.

Significant amounts of heat can also be economically recovered from boiler blowdown by flashing to produce low pressure steam or by using a blowdown heat exchanger to heat incoming make-up water. In operations requiring large blowdown rates due to high dissolved solids, the heat recovery from such a system can amount to as much as several percent of the boiler input energy. (See also booklet on "Steam Management")

Most of the boilers and process heaters in use today were well designed for a low priced fuel economy. With the changing energy climate over the last several years, however, the technical and economic constraints have changed drastically. Reconsideration of boiler operations and of investments in equipment to improve their performance makes good business sense now, and will certainly make even better sense in the years to come.

Waste materials as fuel

While major strides have been made in the last decade in the incineration of municipal garbage to generate energy, the field of industrial incineration has remained largely undeveloped.

There were essentially two reasons why this happened:

1. With fuel at low cost, there was relatively little incentive to recover heat from incineration — and without heat recovery, economics favoured trucking wastes to a landfill site.
2. Some incinerators caused a pollution control problem of excessive particulate matter. Addition of auxiliary emission controls made incineration even less economically attractive.

Obviously, one of these factors has changed considerably. Fuel costs are not only much higher, they are still on the rise. As a result, both incineration and associated heat recovery technology are in full bloom. Starved air, fluidized bed and other types of incinerators can economically convert a wide range of solid, liquid and gaseous industrial wastes into recoverable heat energy, and frequently generate — with or without the help of pollution control equipment — a clean effluent stream of carbon dioxide and water vapour.

These incinerator units are available from a number of manufacturers in a range of sizes to accommodate many plants in the non-General Motors class and can be used both to generate

steam in a separate boiler or to heat air for various industrial applications through a heat exchanger. Case histories of industrial incinerator use are included in a later section of this booklet.

How does a "starved air" incinerator work?

Starved air incineration converts waste to recoverable heat in two steps. The first takes place in the incinerator's main combustion chamber where the following is accomplished:

- a limited percentage of the waste is thermally degraded for the generation of heat
- a portion of the waste is gasified for later use as a fuel in a secondary thermal reactor section
- the carbon-rich char residue is burned out on the hearth

In the main combustion chamber, approximately one-third of the total amount of air needed to achieve combustion is introduced through numerous small holes in the hearth. Rapid combustion occurs in the isolated areas near these orifices and the products of combustion are driven off at very high temperatures. Combustion products filter upward through the mass of waste in the main chamber — raising the temperature of the waste and causing it to gasify. The reactions that occur are complex — with both oxidizing and reducing conditions existing.

As the reaction proceeds, the refractory lining of the main chamber is heated, radiating heat into the trash and providing a thermal flywheel effect as trash is intermittently introduced into the main chamber. The high resulting temperature causes volatile products in the trash to be driven off in a gasification process. Since no oxygen is available for combustion, the gases are predominantly carbon monoxide and hydrocarbons. Finally, the carbon-rich residuals resulting from degasification are burned out on the hearth.

The second step occurs in the thermal reactor or "low-energy support afterburner" section. Here, combustion is completed by introducing preheated fresh air and igniting the gaseous mixture with a pilot light. Because the temperature of the gases from the main chamber is above 1200°F as they enter the afterburner, the pilot light itself does not raise the overall temperature. However, as these gases ignite, temperatures reach 2200°F. Additional air is then introduced through a series of naturally inspirated sections until a minimum of 150% of required air is introduced, ensuring complete combustion.

Limiting the main chamber air input effectively minimizes the resultant turbulence and, hence, the particulate matter generated and entrained in the flue gas. Furthermore, the high pressures generally observed in conventional pyrolysis processes are eliminated, and the main chamber runs at negative pressure. The total combustion is especially pertinent to the heat recovery process since any associated heat exchange device is not subjected to high concentrations of particulate matter.

Heat reclamation.

With the adoption of the principle that thermal degradation of organic matter is controllable, it is now relatively easy, from an engineering viewpoint, to interface the incinerator with the appropriate heat exchange equipment. Recovery of heat from the flue gases is restricted only by the limitations of the heat transfer equipment. Many designs of commercially available flue gas heat recovery equipment have the potential of operating effectively with today's industrial incinerators.

One type of heat exchange equipment that offers a wide variety of design possiblities is the tubular heat exchanger. Multiple shell of tube passes can be provided, resulting in high transfer efficiencies. Hot media can flow inside or outside the tubes, the choice depending largely on maitenance requirements to retain operating efficiencies. A fairly wide selection of materials is available for the tubes, which normally will operate at a temperature approximately equal to the average of the flue gas and the ambient air — or about 750° F.

A typical installation of this type is a tube bundle heat exchanger mounted on the incinerator stack. In this case, the hot flue gases flow on the inside of the tube bundle, and plant air passes on the outside of the tubes. The temperature of the resulting hot air is controlled by adjusting the air flow rate through the exchanger. The heated air can be used for space conditioning or other purposes.

Steam generation.

For the conversion of flue gas to steam, a

preassembled, packaged boiler is recommended. Because the boiler units are nominally the same size and weight as the incinerator, stack mounting is not possible. The boiler is connected to the incinerator by a refractoried run of stack and can be fired by the incinerator alone or by the incinerator and an auxiliary burner. This type of heat recovery is extremely attractive when the plant utilizes either low or high-pressure steam for process heat in the manufacturing area or for building heat. The output of the boiler is connected to a conventional steam header and interconnected to the plant's main steam supply. When the incinerator is in operation, the heat recovery boiler serves as the primary system, and is supplemented by regular boilers when demand exceeds supply.

How economic is incineration vs. trucking?

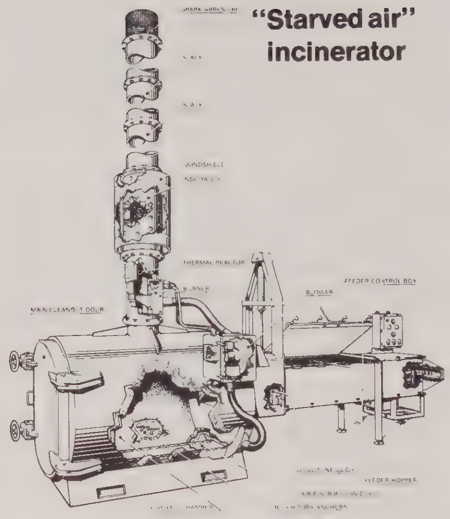
In an era of growing energy requirements and declining fuel supplies, onsite production of energy from wastes can offer significant economic advantages for industrial plants.

To determine if the waste materials generated in a plant can be economically processed for energy recovery, a solid waste and energy requirements survey must be carried out. Data to be obtained are:

1. types of solid waste generated
2. volume of waste material produced per day
3. density (in pounds per cubic yard) of each type of waste
4. total pounds of waste generated per day
5. Btu value per pound of waste
6. total daily Btu output of each type of waste

Dividing total pounds of waste per day by available burning hours (established by the plant engineer) determines the required burning rate in pounds per hour. The average Btu content per pound is calculated by dividing the total daily Btu content by the total pounds per day. The exact capacity of the required pyrolytic incinerator can then be determined.

Once the capital and installation costs of the equipment have been established, it is a simple matter to compare them with what the plant currently spends for hauling the wastes to a landfill or dump.



"Starved air" incinerator

The Btu data from the survey can then be used to compute fuel savings resulting from waste heat recovery.

A word of caution is, however, in order. In many cases, gathering and evaluating data for such a survey requires expert knowledge about waste-handling procedures and fuel cost evaluations. If this expertise is not readily available in the plant, it may be wise to seek outside help. Assistance is usually available from consultants, incinerator manufacturer or a representative in the area.

Typical applications.

The following installations are examples of how onsite incineration processes with auxiliary energy recovery equipment are currently being used in industry. (See also case histories.)

- A cement company burns spent crankcase oil to generate steam for use in cement kilns. The cement acts to neutralize acidics in the flue gas — with electrostatic precipitators on the stack removing remaining particulate matter.
- A Canadian lumber mill burns wood wastes to economically generate steam for use in lumber kilns. The owner claims that the rising price of other fuels would otherwise have forced him to close down his kilns.
- The lesson? If you have large quantities of combustible wastes of any kind at least explore the possibility of incineration as a means of saving energy and dollars.

Burning garbage heats drying oven

The situation: At a U.S. plant of John Deere Limited, management was conscious of a substantial yearly cost of nearly $40,000 to haul garbage from the plant to the nearest landfill site, but they were also conscious that this garbage had a high thermal content and if burned without causing undue air pollution could provide a valuable source of heat for a plant oven or process.

Action taken: The company installed a pyrolysis incinerator to burn nearly 20,000 lbs/day of garbage and, in conjunction with a heat recovery unit, to provide more than 3.9 MMBtu/hr to the plant's paint drying oven. Mix of the garbage burned is 50% lumber, 10% plastic, 40% miscellaneous, with corrugated waste baled and sold. Under the pyrolysis system, combustible gas is generated in the primary burning chamber so that the process "burns up its own smoke"—creating air emissions well within acceptable limits.

Energy savings: 3.9 MMBtu/hr = 14,600 Mcf/yr.

Dollar savings: 14,600 Mcf/yr @ $2.00 Mcf = $29,200./yr.

Additional savings in eliminated waste haulage: $38,400/yr.

Cost of improvement: For incinerator and heat recovery unit: $110,000.

Recommendation: Consider plant wastes as a potential heat source for your plant. As energy costs increase—along with trucking costs for haulage to disposal sites—waste incineration will represent an even more attractive energy conservation investment. It is estimated that, depending on composition, garbage is often worth up to $10/ton in recoverable energy.

Burning waste gas generates steam

The situation: An oil refinery has an acid gas by-product that contains a relatively high percentage of hydrogen sulfide and thus could not be vented to the atmosphere without treatment. Management seized the opportunity to make use of the 39,140 lb/hr of flue gas as source of waste heat.

Action taken: The H_2S rich gas is mixed with air and burned at 2,500°F. No additional fuel supply is required. The combustion air is then cooled to 650°F in a waste recovery boiler where it generates 27,835 lb/hr of 175 psi steam. As a final step, the flue gas enters a converter which extracts sulfur.

Energy/dollar savings:

From the combustion gas,
Energy
= 39,140 lbs gas/hr x 0.366 Btu/lb°F x (2500—650)°F
= 26.5 MMBtu/hr

At a feedwater temperature of 300°F, the energy required to produce 1 lb of steam at 175 psig from water at 300°F is 933 Btu/lb (from steam table).
With a 2% heat loss,

Steam flow
= 26.5 MMBtu/hr x 1/933 Btu/lb. x (1 — .02)
= 27,800 lb/hr
Based on a cost of $1.20 per 1,000 lb. of steam and 4,000 hour per year operation,
Annual savings
= 27,800 lb/hr x $1.20/1,000 lb x 4,000 hr/yr
= $133,000 per year.

Cost of improvement: Not available.

Recommendation: Evaluate waste products as energy sources to supply heat for the production of steam, for space heating and other plant requirements. Often these systems can be used to eliminate pollution problems.

Combustion air intake relocation saves energy

The situation: At the Nackawic, N.B. mill of St. Anne-Nackawic Pulp & Paper Company the recovery boiler—burning black liquor solids—forced draft fan air intake duct was located on the ground floor of the building where available air was a relatively cool (50-60°F in winter). Preheating of this combustion air to 200°F+ was carried out using steam coils.

Action taken: 50 feet of fibreglass ducting was added to relocate the air intake to the top floor of the building where temperatures are in the order of 100°F—reducing requirements for steam for combustion air preheating.

Energy savings: 4 MMBtu/hr.

Dollar savings: 4MMBtu/hr × 11,250 hrs/yr × $2.00/Btu/hr = $90,000/year.

Cost of improvement: $88,500.

Recommendation: Consider relocating air ducts at the source of warmest available air to reduce preheating requirements. In this particular application, costs were particularly high due to need to reinforce ducting and attach firmly to the building to reduce vibrations—and due to design complications tying into the existing air intake.

Combustion air preheated with kaolin

The situation: A company which manufactures kaolin powder as a base material for paint realized that it could recover considerable amounts of heat previously vented to the atmosphere from its process. A hot clay air mixture with a temperature of 1450°F and a flow rate of 41,000 lb/hr to the bagging room offered a convenient source of energy to preheat combustion air for a gas-fired furnace.

Action taken: A heat exchanger was installed in which the kaolin air mixture is cooled from 1450°F to 400°F and the heat acquired used to preheat 7950 cfm of furnace combustion air to 1140°F from its ambient temperature of approximately 80°F.

Energy savings: 41,000 lb/hr × 0.308 Btu/lb°F × (1450-400)°F = 13.3 MMBtu/hr

With the heat exchanger operating 6000 hr/yr at its design efficiency rate of 70 per cent, yearly energy savings = .70 × 13.3 MMBtu/hr × 6000 hr/yr = 55,800 MMBtu/yr

Dollar savings: 55,800 MMBtu/yr = 55,800 Mcf @ $2.00 Mcf = $111,600/year

Cost of installation: $90,000.

Recommendation: Don't overlook any possible source of waste heat for preheating combustion air or for other applications.

Garbage supplies heat for plant

The situation: A fabricator of plywood, fibreboard and insulating materials in Wisconsin opened a new plant and found it impossible to get guaranteed supplies of natural gas. In retrospect it may now appear fortunate that natural gas is in short supply because it forced the company to look at 5,000 tons of combustible waste (which would have been hauled away to a city incinerator) as fuel for heating the plant. It was seen that the plant would only be able to use 60 percent of the heat generated by burning trash, with the remaining 40 percent being discharged to the atmosphere.

Action taken: The company installed a pyrolysis type incinerator (with oil as a standby fuel for weekends) which, in concert with a heat recovery system is recovering a net 5,500,000 Btu/hr. In the system, waste scraps of raw material, office and other trash, are pushed into a primary chamber from a feeder bin by hydraulic ram. Here they are burned under oxygen lean conditions, which produces a combustible gas. When this gas rises with the smoke into the base of the emission stack it passes through a thermal reactor where air is brought in from the outside. Gas and smoke are then burned at temperatures of around 2,000°F. 1,800°F hot air is diverted by a fan into a boiler where it heats water which, in turn, heats the hot air used for plant conditioning.

Energy savings: 5.5MM Btu/hr = 34,320 MMBtu/yr = 34,320 Mcf/yr

Dollar savings: 34,320 Mcf/yr @ $2.00 /Mcf = $68,640./yr.
Approximately $20,000/yr in haulage costs for waste was also saved.

Cost of improvement: Approximately $150,000.

Recommendation: Attempt to reduce the amount of "garbage" generated by your plant, but where waste production is unavoidable and is available in sufficient quantities, look to it as a source of heat for various purposes. Pyrolysis incinerators generally produce a low volume of dry, sterile ash. In the case of the Wisconsin company, management is now studying ways to direct some of the unused heat to paint drying ovens—further reducing the firm's energy bills.

Heat wheel captures waste heat from annealing furnace

The situation: Annealing furnaces used for heat treating metal products in Standard Tube of Canada's Woodstock, Ontario plant were consuming major amounts of plant oxygen and creating excessive amounts of carbon dioxide. The result was a request from the Ontario government to consider a ventilation system. Standard Tube's approach was to provide the needed ventilation and at the same time capture the latent energy in exhaust and other heated air that was accumulating just below the plant roof.

Action taken: The decision was taken to install a metal heat wheel to capture waste heat and pre-heat plant make-up air during the winter. An H-shaped grid collects 30,000 cfm of 120°F air at ceiling (2,500 cfm oven exhaust air plus 27,500 cfm ambient air heated by oven's radiant heat) and feeds it into the heat wheel.
Outside air is heated to approximately 90°F, depending on outside ambient temperatures, before being ducted to plant floor level.
A manually operated bypass allows direct venting and air intake whenever outside air temperature exceeds a predetermined point.

Energy savings: Based on a 210-day use cycle, savings (over the conventional exhausting of warm air and heating make-up air with direct fired gas heaters) are estimated at 10,000 MM Btu's per year on a three shift basis over a 210-day use cycle.

Dollar savings: Savings approach $20,000 per year, based on a $2.00/Mcf cost of gas.

Cost of improvement: Cost of the heat wheel itself was $8,000. Capital required for entire project including labour, duct work, etc. totalled $60,000. Experience so far indicated that the investment will be recouped within a 3-year payback period.

Recommendation: Consider the use of heat exchange devices included heat wheels to recover heat from exhaust gases. In the case of Standard Tube, a ventilation system was required in any event and the actual payback period related solely to the use of the heat wheel is in the order of one year. Similar economics may well apply to an application in your plant.

Improved furnace insulation cuts heat loss

The situation: Bending furnaces with a maximum internal temperature of 1200°F in a U.S. plant had sidewall and suspended crowns constructed of heavy red and refractory brick. Although the walls were thick, it was obvious to management that heavy heat losses in the furnace was being incurred.

Action taken: The crown of the furnaces was replaced with sheet metal and low density ceramic fibre insulation. Insulation was also added to furnace walls.

Energy savings: Due to heat up time reduction from 2½ hrs/day to 30 min/day = 3 Mcfd. Total daily savings = 4.4 Mcfd.

Dollar savings: 4.4 Mcfd @ $2.00 Mcf = $8.80/day × 210 days/yr = $1,848/year.

Cost of improvement: $1,750.

Recommendation: Consider similar insulation projects for ovens, kilns, or furnaces in your plant. In this case, there were a number of other intangible benefits which were not taken into account in justifying the investment involved: ambient temperatures near the furnaces were lowered by 20°F, production rates and product quality were improved and maintenance requirements were reduced.

Incinerator effluent preheats oven air

The situation: At the Wallaceburg, Ontario container factory of Libby, McNeill & Libby, provincial air emission standards dictated the installation of a fume incinerator to control hydrocarbon emissions, eliminate air and odour

pollution and remove the problem of condensate particles contaminating tin plate moving through the gas-fired sheet oven.

Action taken: The company installed an incinerator incorporating a heat recovery system to utilize incinerator exhaust to preheat oven entering air.

Energy savings: A maximum of 1.1 MMBtu/hr is supplied by the incinerator effluent to preheat oven air.

Dollar savings; 1.1 MMBtu/hr × 4500 hr/yr = 4950 MMbtu/yr = 4950 Mcf/yr @ $2.00/Mcf = $9,900/year.

Cost of improvement: Of a total project cost of nearly $300,000, costs attributable to the recovery system amounted to just over $150,000.

Recommendation: Look closely at pollution abatement program as ideal opportunities to "piggyback" energy conservation programs. In the case of Libby's, use of the heat recovery system resulted in natural gas consumption for the oven and incinerator totalling less than 10 percent higher than natural gas usage required previously for the oven alone.

Insulation of continuous cooker cuts heat loss

The situation: At the Wallaceburg plant of Libby, McNeill, and Libby, management is aware that heat loss from Sterilmatics (automatic continuous steam cookers for sterilizing tin food products) represents one of the significant energy savings opportunities within the plant.

Action taken: As a result they are planning to insulate the three Sterilmatics at the plant using a 3-inch polyurethane shell enclosed in a 26-gauge stainless steel jacket.

Energy/Dollar savings: Approximately 6,350 Mcf @ $2.00/Mcf = $12,700/year.

Cost of improvement: $21,000.

Recommendation: Look to insulation of any combustion or heat process equipment to reduce fuel consumption.

Modification of firing processes minimizes energy use

The situation: A U.S. company involved in the manufacture of computer components was faced with a situation in which computer memory cores were being fired in a kiln for 18-24 hours when all that was required was a few seconds at the maximum temperature (usually 1,000°C). The long cycle was necessitated by the characteristics of the furnace and of the plates which supported the cores. First, it was difficult to be sure that the cores reached the right temperature without overshoot; second, the plates were sensitive to temperature shock and had to be heated and cooled slowly.

Action taken: In an improved process, the cores were spread on a woven belt of platinum wire which carried them continuously through a small tube furnace about four feet long. The cores were exposed to high temperature for only about 15-20 seconds. The continuous process permitted frequent sample testing of the cores with feed-back of information for any desired adjustment of temperature, oxygen content of the furnace atmosphere, etc. As a result the yield of "good" cores at the final quality control test station was more than doubled.

Energy savings: Process changes reduced the energy requirement for firing computer cores from 120 Kwh/M cores to slightly less than 0.9 Kwh/M cores.

Dollar savings/Cost of improvement: Not available.

Recommendation: Keep kiln firing schedules as short as possible and reduce to a minimum the amount of heat loss through heating and cooling the supporting kiln furniture. Wherever possible, continuous firing should be implemented.

New boiler pays for itself promptly

The situation: A U.S. food processing company reviewed its capabilities to increase production and concluded it would be to its advantage to "reboiler" their plant. Two original boilers with oil burners had earlier been converted to gas/oil firing and were rated at 600 HP each. In order to provide additional peak capacity, a 200 HP boiler

was rented each year for August and September. Since business was expanding, even more steam would be needed in the future. It was also recognized that gas supplies were being curtailed and changeover of this old gas burner to oil firing was a bothersome process that took many man hours— and, tests indicated that the old boilers were operating at a fuel-to-steam efficiency of about 70%.

Action taken: It was decided that a new 800 HP boiler (85% efficiency) with a combination gas and oil burner be installed. At the same time, a shell and tube heat exchanger was installed to preheat boiler feed water with 150° waste water from the blanchers, cookers and brine heater.

Energy/dollar savings: The total cost of the heat exchanger installed was $3,000, and the fuel saved due to the heat recovered was approximately $6,000/yr. The higher efficiency of the new boiler, compared to the old boilers, resulted in further cost savings:

Old boilers:	1,799,981 Cases with	66,177 MMBtu
New boilers:	1,821,285 Cases with	48,812 MMBtu
Gain:	21,304 Cases with	17,365 MMBtu

This saved an additional $28,000 in fuel costs. Two other factors contributed an additional $20,000 savings. First, a rental boiler was not required for peak periods. Second, more than 2,000 man hours were saved, since the new boiler was automatic, and changeover from gas to oil only takes minutes, not hours.

Total savings: $48,000/yr + $6,000/yr = $54,000/year

Cost of Improvement: $67,000.

Recommendation: Replace outdated, inefficient combustion equipment wherever energy and other savings make it economic to do so. Some manufacturers guarantee high fuel to steam efficiency in new boilers.

Noxious material burned to generate steam

The situation: A chemical manufacturing firm was faced with a disposal problem for substantial quantities of a liquid chemical by-product.

Action taken: The company installed a boiler to burn the by-product which has an average heating value of 6,000 Btu/lb and is completely oxidized at 1,800°F. The boiler has special designs to control boiler and soot deposits and generates 64,000 lb/yr of 300 psig process steam. A total of 200,000 cfm of flue gas is produced and quenched to 200°F before passing through a scrubber into the stack.

Energy/dollar savings: The flue gas flow rate corresponding to 200,000 cfm at 1800°F is 170,000 lb/hr. The specific heat of the flue gas is 0.30 Btu/lb °F and the saturation temperature of 300 psig steam is 422°F. The waste heat boiler was designed to have an exit flue gas temperature of 500°F. Therefore, the energy available from the flue gas is:
Energy available — 170,000 lb/hr $\times$ 0.30 Btu/lb. °F $\times$ (1800 − 500) = 66.3 MMBtu/hr.

If the feedwater is at 220°F, the heat required to produce saturated 300 psig steam is 1027 Btu/lb. Allowing for 1% heat loss;
Steam production = 66.3 MMBtu/hr $\times$ 1 lb/1027 Btu $\times$ 0.99 = 63,900 lb.hr.

The company was paying $1.25 per 1,000 lbs. of steam when it was produced from fuel oil. Based on 3,000 hrs. per year operation;
Dollar savings = 63,900 lb. steam/hr $\times$ $1.25/1,000 lb. steam $\times$ 3,000 hr/year = $240,000 per year.

No allowance was made for savings due to reduced disposal costs.

Cost of improvement: Boiler = $400,000. Installation and accessories = $300,000.

Recommendation: Liquid by-products and solvents should be considered as fuel sources for steam generation, space heating, etc. Higher prices for fuels make these processes more economical.

Oxygen analysers installed, combustion controls upgraded on boilers

The situation: Labatt Breweries of Canada Limited's boilers function using a batch process. It is physically impossible to respond manually to the changing load.

Action taken: Labatts decided to install oxygen analyzers and upgrade to fully automatic the

combustion controls on boilers in its Montreal Brewery. The automatic controls make it possible to respond quickly to the load change factor.

Energy/dollar savings: Projected savings are 1.25% of fuel consumption or 5,000 Mcf of natural gas per year.

Cost of improvement: $60,000 installed. The project was justified economically by assuming a 15% escalation in fuel cost each year for the first three years and a 10% per year escalation thereafter. This would mean a discounted cash flow rate of return on investment of 20% with a payback period of 4 years.

Recommendation: Use projections for future cost escalations to determine economic viability for energy conservation projects.

Preheated combustion air saves gas at glass plant

The situation: A glass company, a part of ordinary maintenance, decided to save energy by using stack recuperator to preheat combustion air. A day tank was rebuilt and provided with two flat-flame burners, a 16-oz. blower, and a zero regulator air-gas mixer. The tank was oval, approximately 6 ft. × 8 ft. with a 12-inch high metal lining. The holding capacity was 3.5 tons of glass.

Action taken: While the equipment and tank design were unchanged, the stack operation was changed from downdraft to updraft. The recuperator was set on a refractory stack base approximately 48 inches high and the new stack was built over the top of the existing stack at floor level with a cleanout and/or cold air entrance. The unit was designed to withstand 2,100-2,300°F, using ⅛ inch Incoloy 800 for the recuperator and 1/16 inch stainless steel for the stack. The centre pipe was approximately 7 ft. long and 24 in. in diameter, with vertical strips 3 in. long and ⅜ in. wide welded on the outside. A larger concentric pipe of the same length fitted over the centre pipe, leaving an air space of ⅜ in. between the pipes. The outer pipe was covered with insulation and the insulation was then covered with a metal shield. Six-inch diameter inlet and outlet pipes were fitted to the outer pipe.

Energy savings: The annual (50 weeks) gas savings for melting and holding amounted to 4,212,500 cu. ft./yr (16,587,500 cu. ft./yr. before installation of the recuperator and 12,375,000 cu. ft./yr. after installation) for melting and holding operations.

Dollar savings: At a cost of $2.00 Mcf, the savings for fuel are: (4212.5) ($2.00) = $8,425/year.

Cost of improvement: The 1971 cost of installation was $4,520—doubling this to $9,040 for 1977 gives a payback of $\frac{\$9,040}{\$8,425} = 1.07$ years.

Recommendation: Stack recuperators can be an attractive option to preheat combustion or other air.

Recuperators heat make-up air with kiln exhaust

The situation: At a Canadian abrasives products finishing plant, an energy audit showed that substantial amounts of heat were being wasted in the form of kiln flue gas.

Action taken: Over a period of four months, vertical, surface-type recuperator heat exchangers were installed on each of the plant's six kiln flues. Over a 10-day cycle necessary to avoid heat shock to the grinding wheel being baked, flue gas varies in temperature between 200 and 1800°F. Fresh air is preheated by 10° to 60° depending on the heat of flue gas and finally "trimmed" by a direct gas fired heater with a 25:1 turndown ratio. The air then passes into the plant ventilation system.

Energy savings: 4,680 MMBtu/yr = 4,680 Mcf/yr.

Dollar savings: 4,680 Mcf/yr @ $2.00/Mcf. = $9,360/year.

Cost of improvement: $17,000.

Recommendation: Look to flue gases as an available source of waste heat. Pay full attention to operator education with the new system. Experience shows that with proper education, start-up problems can be minimized.

Reducing excess air in steel foundry furnace

The situation: Dominion Foundries and Steel's fuel-fired heat treating furnaces often require excess air to ensure temperature uniformity. However, the amount of excess air on a particular furnace is sometimes higher than that required for temperature uniformity.

Action taken: In one of the furnaces in the steel foundry, air flow must be held constant throughout the cycle. Dominion Foundries and Steel tried reducing this constant flow of air on successive cycles in small increments while carefully monitoring furnace temperature spread and product quality. The company found that it was able to reduce air flow by about 40% for this particular 10 × 21½ ft. furnace, without significantly affecting temperature uniformity.

Energy savings: This measure saved 12 MMBtu/cycle × 416 cycles/year = 4,992 MMBtu/year.

Dollar savings: 4,992 MMBtu/year coke oven gas at $2.00/MMBtu = $9,984/year.
Figures for cost of testing the air flow for the furnace are not available.

Recommendation: Each furnace has to be tested as an entity of its own, and care must be taken so that the air is not cut back too much causing damage due to lack of temperature uniformity. If you can spare the money and time to conduct the tests properly, this measure can be a big energy saver.

Scrap plastic burned in boiler

The situation: At a General Motors plant, 24,000 lbs. per year of scrap plastic was granulated and sent to a landfill site for disposal. One major boiler was fueled with stoker coal, despite the high Btu content of the plastic waste.

Action taken: A simple vacuum system was installed on the boiler to allow mixing of coal with the granulated acrylic, ABS, polypropylene and polycarbonate material.

Dollar savings: 360 MMBtu/yr = 13.8 tons stoker coal @ $40/ton = $552/year.

Cost of improvement: $750.00.

Recommendation: Careful consideration should be given to the use of plastic and other waste materials as combustion fuels (see other case histories). To the basic energy savings offered in many cases must be added the elimination of substantial waste removal expenses. Plastic materials have a high thermal content and generally leave relatively little ash, however, some such as polyvinyl chloride give off noxious gases and other residues when burned and must be approached with a good deal of understanding before any attempt is made to utilize them as a source of energy.

Slot furnace modernization improves efficiency

The situation: John Deere Limited's Welland works utilizes a number of slot furnaces. As part of an overall energy audit, the company realized that these furnaces could be re-designed to make more efficient use of energy. In fact, preliminary estimates indicate that a new design furnace could save approximately 19 percent on fuel consumption. Actual in use savings proved to be more than twice this amount.

Action taken: After prototype testing, new furnaces were put in place which incorporated the following features.

—Castable ceramic lining — rather than refractory brick.
—Preheating of combustion air to 400° by mixing ambient air with furnace exhaust.
—Replacement of water-cooled heat shields with fibrefrax ceramic fibre.
—A new design arch block with improved heat reflection which can reduce material heat-up time by up to 40 percent.
—Use of individual 3 hp blowers rather than a central 40 hp blower system.

No external approvals were required and old furnaces were replaced, without interrupting production, at the rate of about 1 furnace per month.

Energy savings: 45 percent overall = 580 MMBtu/year.

Dollar savings: 580 MMBtu/yr = 3,135 gal @ $.35 = $1,097/year.

Cost of improvement: $5,300 per furnace — representing a 41% discounted cash flow return on investment over a 3-year cash payback.

Recommendation: Explore the modification or re-designing of existing equipment in your plant or foundry. Do not be deterred by, for example, a three year "payback". As in the case of John Deere, a dcf rate of return analysis along with other factors (annual maintenance costs were reduced by $870 per furnace) was enough to convince management of the investing of money to save energy — and make money.

Waste oil provides heat for boiler

The situation: At the International Harvester plant in Chatham, Ontario, 5,000 gals/yr. used lubrication oil (such as spent crankcase oil) was being discarded as an unusable waste material. The company realized that, if gathered and stored, waste oil could be used as a fuel for combustion.

Action taken: The company instituted a programme in which waste oil is collected from various locations around the plant such as lift truck and vehicle maintenance departments and deposited in a central holding tank. Three times during the year the oil is transported to the main boiler house fuel tank and mixed with No. 6 Bunker C fuel oil.
The main fuel tank has a capacity of 50,000 gallons and is held at approximately 150°F. The relatively high temperature of the fuel oil, coupled with the fact that the lube oil is introduced into the bottom of the tank in approximately 1,750 gallon lots, enables a good mix to be maintained. No noticeable stratification is apparent.

Energy/dollar savings: 5,000 gals/yr. salvaged oil provides an estimated 960 MMBtu/yr @ $2.00/MMBtu. = $1,920/yr.

Cost of improvement: Labour costs for transporting and pumping oil = $80/year.

Recommendation: Look to a variety of waste materials as potential boiler, kiln or furnace fuels.

Tips on saving money through combustion control

Furnaces, Kilns and Ovens.

1. Calculate and plot boiler efficiency daily.
2. Establish a definite burner maintenance schedule.
3. Regularly adjust burners for most efficient operation.
4. Heat oil to proper temperature for good atomization.
5. Eliminate combustible gas in flue gas.
6. Reduce combustion air flow to optimum level.
7. Replace obsolete burners with more efficient ones.
8. Use waste and by-products as fuel wherever possible.
9. Limit and control secondary combustion air in furnace operations.
10. Calculate a "heat balance" for all combustion equipment to better understand where energy is dissipated or used.
11. Utilize hot stack gases as an energy source.
12. Insulate furnaces, kilns and ovens to minimize heat loss.
13. Control infiltration of cold air into furnaces.
14. Shut down idle combustion whenever possible.
15. Consider cam controllers or other systems to control the shut down cycle on combustion equipment.
16. Schedule plant operations for "full load" operations on combustion equipment.
17. Minimize energy loss during loading and unloading (cycling).
18. Eliminate "overdesign" in equipment and practices.
19. Regularly analyze flue gases.
20. Watch for gasket and seal leaks caused by frequent opening and closing of the furnace.
21. Look into automatically controlled flue dampers.

Industrial boilers.

1. Look to stack gas temperatures as a running indicator of boiler performance.
2. Carry out frequent checks of boiler performance.
3. If more than one boiler is in use, sequence boiler use in decreasing order of efficiency.
4. Keep as many boilers as possible operating near full load (rather than having a greater number operating at partial capacity).
5. Keep all heat transfer surfaces clean.
6. Improve boiler control systems.
7. Reduce "excess air" to increase boiler efficiency.
8. Look to waste heat boilers and/or economizers to utilize hot stack gases.
9. Utilize boiler blowdown as flash steam or in a blowdown heat exchanger to preheat make-up water.
10. Reduce blowdown through feedwater control.

See "Saving Money Through Steam and Compressed Air Management" for further tips.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg{\cdot}m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

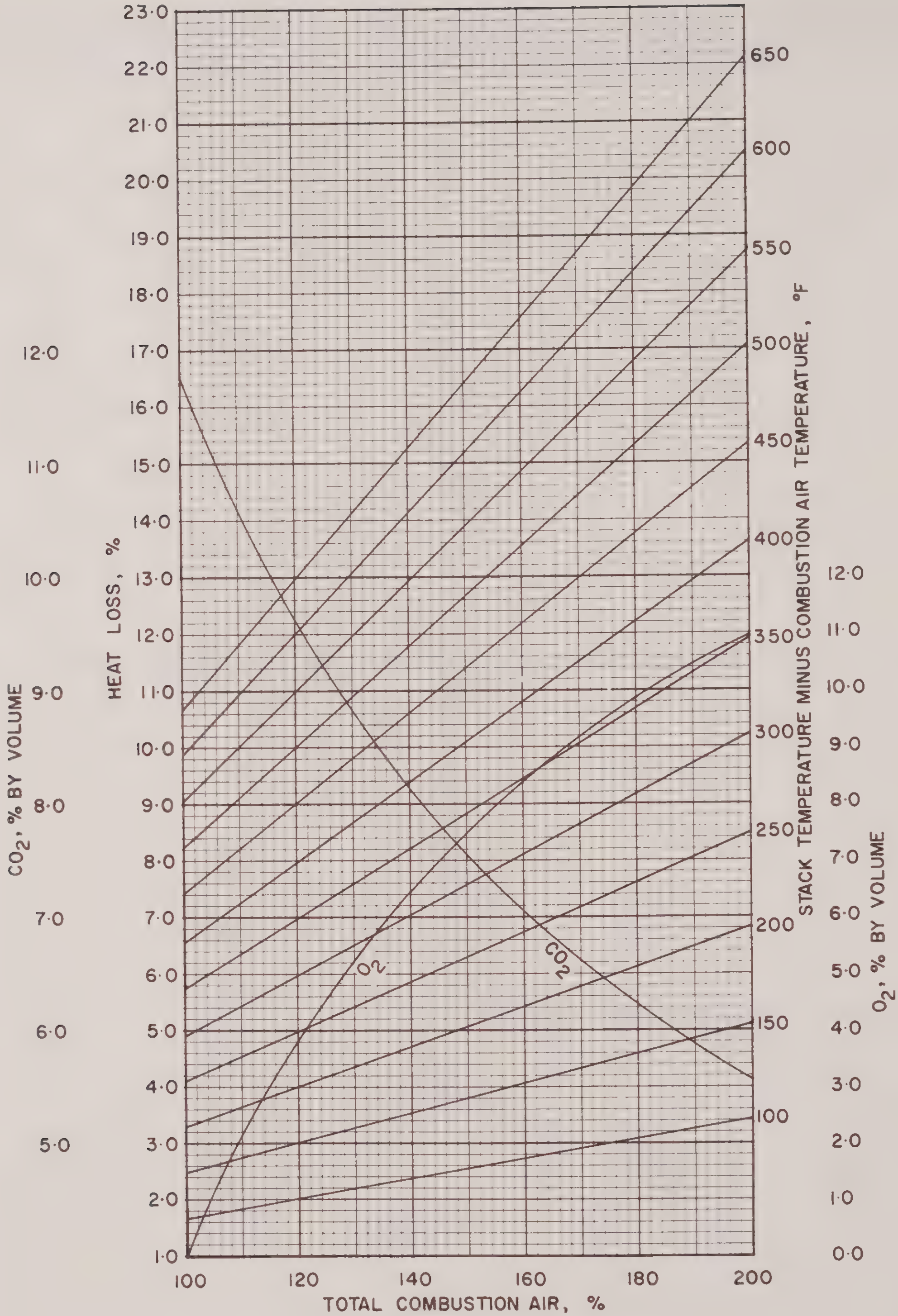
SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

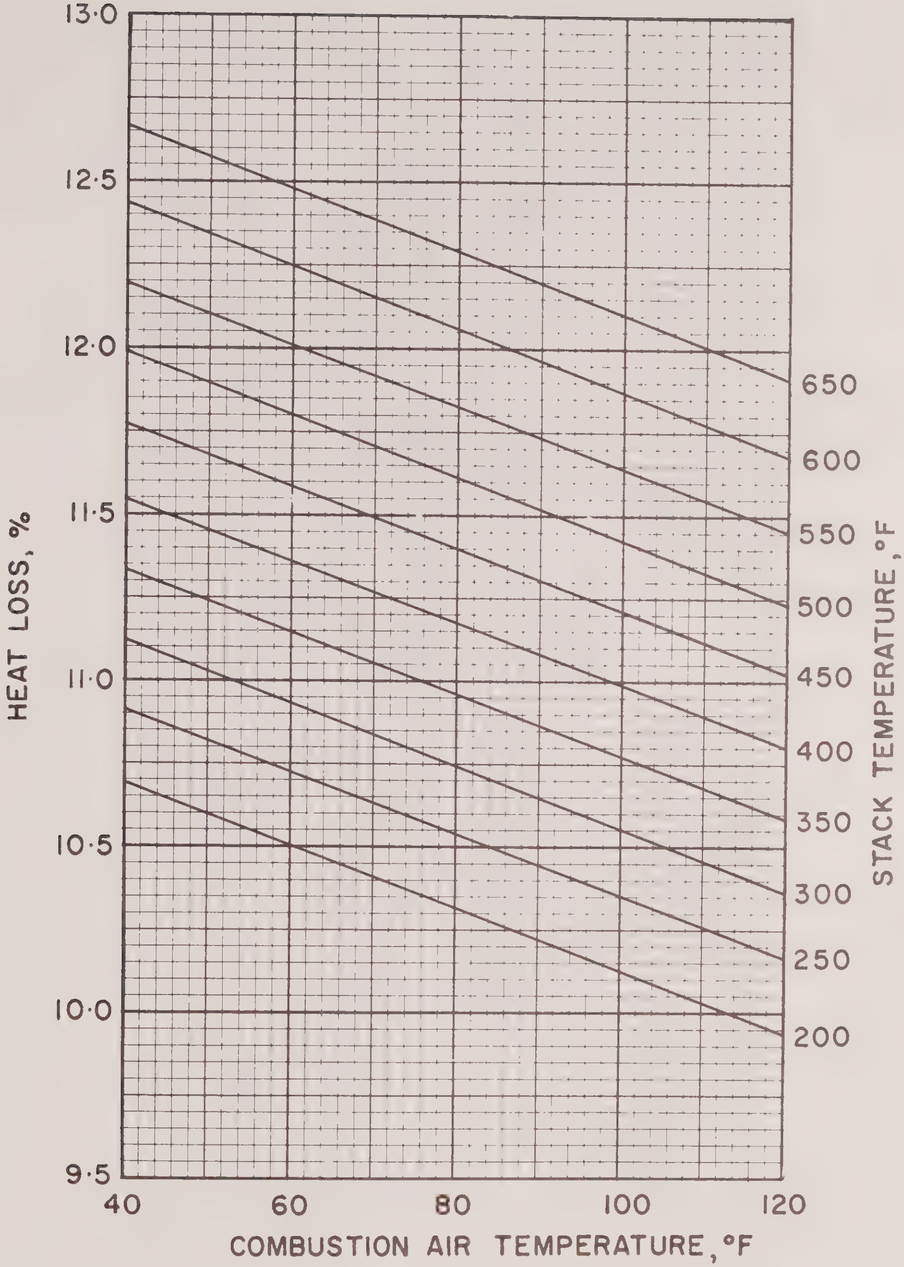
Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1° = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

Appendix

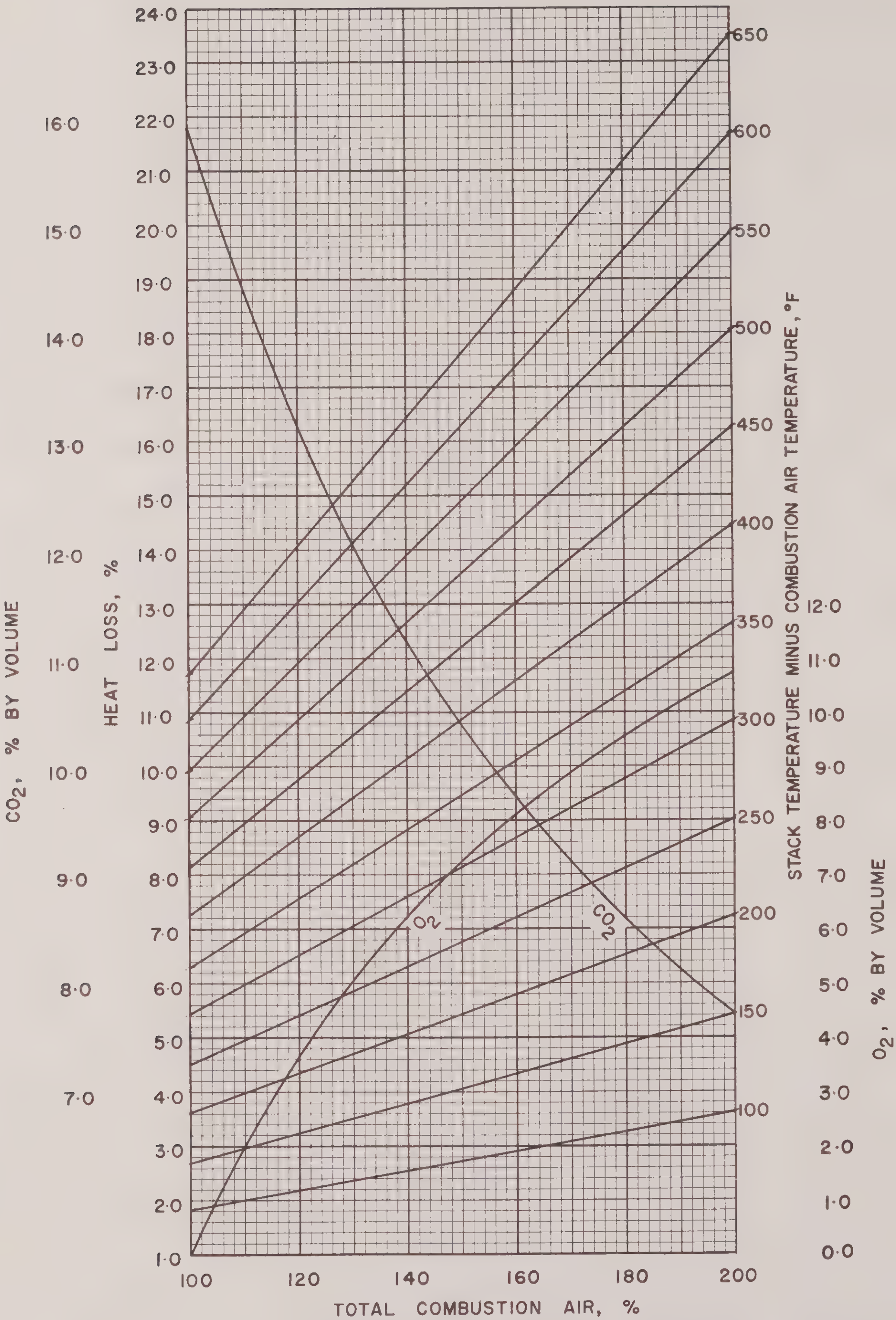


DRY FLUE GAS LOSS FOR A RANGE OF
TEMPERATURE DIFFERENTIALS
FUEL: NATURAL GAS, 1007 BTU / CU FT



HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES.

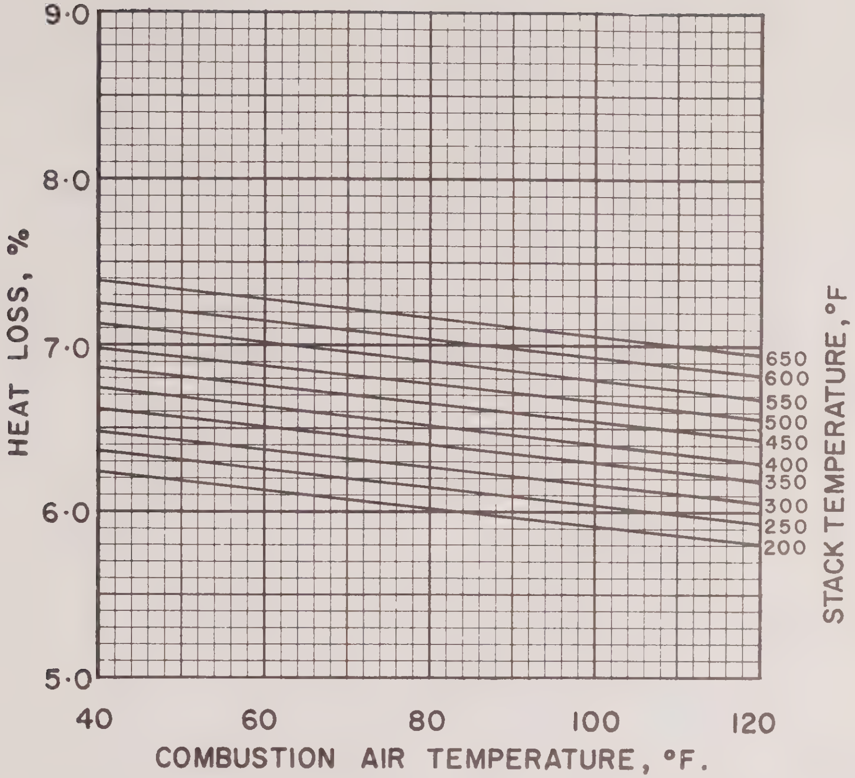
FUEL: NATURAL GAS, 1007 BTU/CU FT.



DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

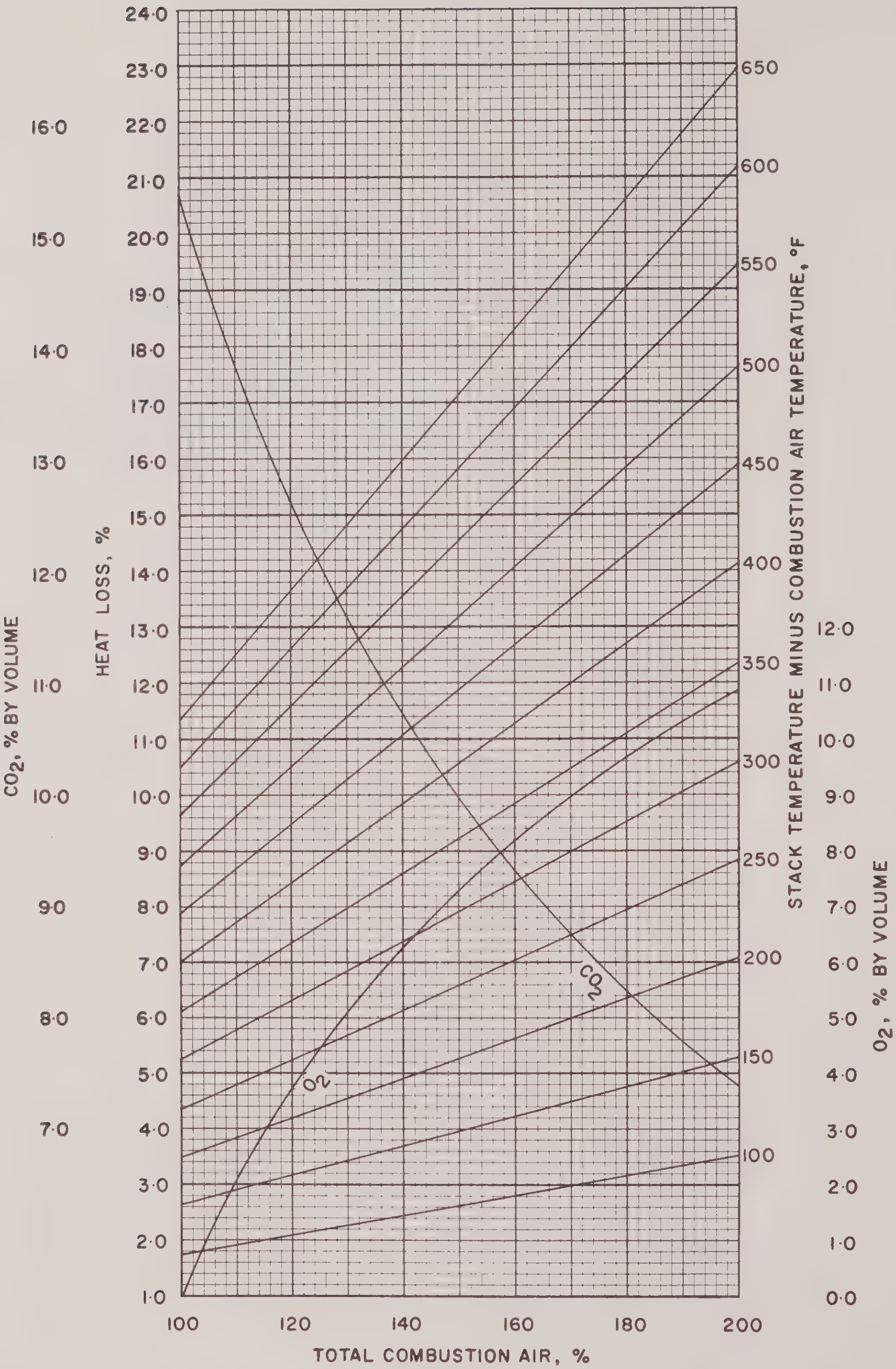
(NO. 6 FUEL OIL)

9720



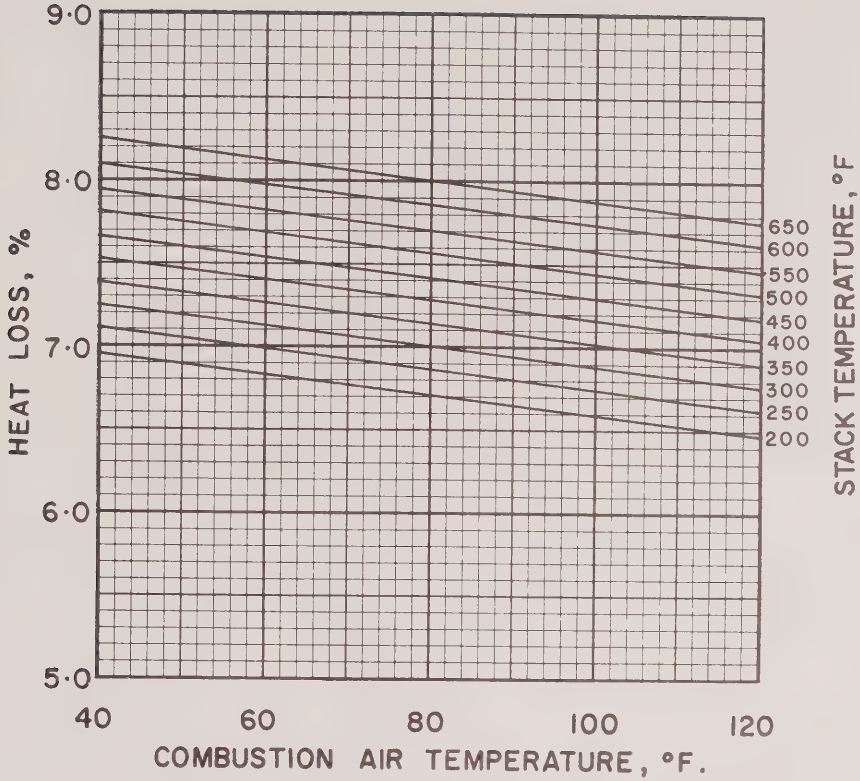
HYDROGEN LOSS FOR A RANGE
OF STACK TEMPERATURES.
(NO. 6 FUEL OIL)

9720



DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS.
(NO. 2 FUEL OIL)

8507



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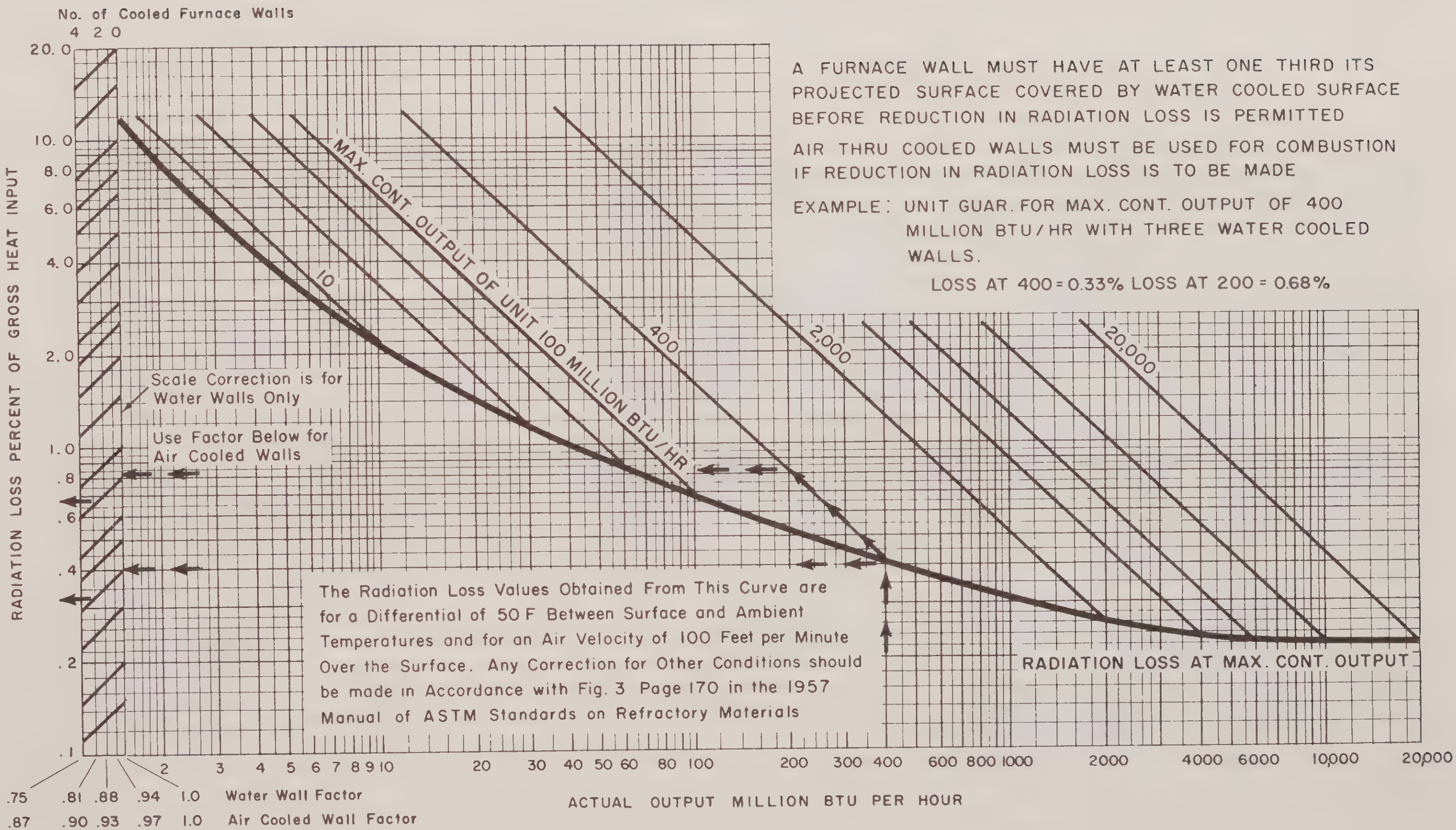

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SAVING MONEY THROUGH STEAM AND COMPRESSED AIR MANAGEMENT

6

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SAVING MONEY THROUGH STEAM AND COMPRESSED AIR MANAGEMENT 6

Saving money through Steam and Compressed Air Management

Introduction:

Both steam and compressed air management offer the plant manager substantial potential for energy savings through a number of different types of conservation programs.

This booklet is largely devoted to effective operation and design of conventional steam and compressed air systems. Other information pertaining to boiler operation, production of steam from waste heat and other related subjects can be found in other booklets in this series. A cross referenced index to these subjects can be found in The Guidebook/Index.

Steam management

Steam is a conveyor of heat, and it was chosen many years ago for this purpose because of two basis properties: first, its ability to be generated from water which was easily available, and secondly, because it was able to store and carry a large quantity of heat at a temperature at which it could conveniently be used.

However, it now appears that the main quality which made steam valuable — its ability to carry heat — has led many people to take it for granted. Perhaps the fact that steam has been used for so long in industrial processes has given some of the bad habits regarding its use "grandfather" status in the hierarchy of plant practices; but, it is more likely that many engineers take its use for granted because so much of the heat in steam is *latent* or hidden.

One pound of steam at atmospheric pressure contains 1,151 British Thermal Units (Btu's). If there was no such thing as latent heat and if steam at atmospheric pressure was an ordinary gas to which 1,151 Btu had been added — it would have a temperature of 2,300°F. Would anyone ever waste steam at atmospheric pressure if it were a searing incandescent gas that would raise metals to white heat, and soften or melt all pipes and vessels? Not likely.

However, most of the heat in steam is latent. In fact, 971 Btu must be added to turn a lb of water at 212°F into one pound of steam at the same temperature. We cannot see this latent heat. We cannot feel it. So, in many cases, we waste it.

For many people in industry these facts are so rudimentary as to be unworthy of comment. Many companies have been aware of the precious nature of steam as an energy commodity for many years and have been actively working to conserve its use. But even these companies have become more receptive to energy conservation programes related to steam use in recent years as the cost of fuel used to generate steam has continued to escalate.

Now, more than ever, it is essential to have a steam system in a plant which operates efficiently and without unnecessary losses. Now, more than ever, it is essential that once water has been treated, heated, vapourized, and condensed in steam lines, that heat not be wasted by flushing condensate — at up to 212°F — down the sewer, or sending 212°F "flash" steam up a vent pipe.

Steam conservation is on the move. The following pages should help any company to climb on the bandwagon.

An efficient system.

A basic understanding of the operation of a simplified steam system is, understandably, fundamental to any attempt to conserve energy in this area.

The simplified diagram shows a steam system and gives an indication of a number of places where energy can be lost. Obviously, the first place to look for inefficiencies in a steam system is in the boiler itself.

Boiler efficiencies — the first link in the chain.

From basic principles, the efficiency of a steam generating boiler is its ability, as a complete system, to transfer the energy of the fuel burned to water and steam. This efficiency is dependent on the excess air of the burner and the heat transfer design on the boiler. The lower the

excess air and the better the heat transfer characteristics, the greater the efficiency of the unit. Other factors to be taken into account include boiler blowdown and preheating feedwater or combustion air.

Many of these topics are dealt with elsewhere in this booklet or in another booklet in this series (How To Save Money Through Combustion Control). But the burner is perhaps the most critical element to control the efficient use of fuel in a boiler and, it goes without saying, that a burner out of adjustment can waste large quantities of fuel.

Frequently, the following type of problem occurs: improper air flow to a burner, or a poorly adjusted burner, causes smoking because of incomplete combustion. The operator raises the total air flow to the furnace to control the smoking and meet air pollution standards — as a result, the excess air on the system goes considerably beyond the design point, and large amounts of fuel are wasted.

While gas burners do not generally require too much attention, oil fired units are quite sensitive to fuel changes. In fact, the viscosity of fuel oil must be maintained at a set level to permit sufficient atomization and proper air mixing. In addition, the fuel oil analysis should be reviewed frequently to ensure that the correct temperature is being maintained.

Burners are frequently sized by the manufacturer at the time of sale for a specific fuel analysis and a specific heat input, and if these fuel characteristics change, serious consideration should be given to modifying the existing burners or purchasing new ones. Attention to details like these will pay for itself many times over in fuel savings.

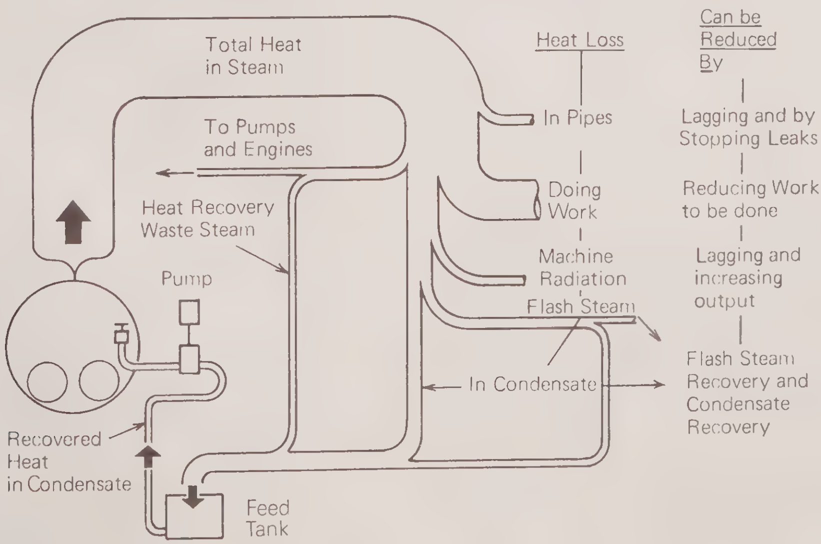
One way to minimize the number of man-hours which have to spent to assure maximum combustion efficiency is to install an up-to-date combustion control system. It's a step that could follow many others more basic in increasing the efficiency of the system, but where other lower cost measures have already been introduced, installation of sophisticated instrumentation and control hardware will help wring the last efficiency dollars out of a boiler system. Each plant application requires its own analysis, but in general, the return on investment and payback period from improved combustion control is very attractive.

Some plant managers consider combustion controllers economical only on large boilers (300-500 hp) and, on smaller boilers, rely on frequent analysis of flue temperatures and oxygen or carbon dioxide content.

Boiler tubes must be clean.

Moving further along the system, the heat transfer rate of boiler tube surfaces is an important consideration. Not unexpectedly, the amount of heat transferred by these surfaces varies directly with their cleanliness. Accumulations of fouling encrustations on

Where the heat goes in a steam system



internal or external tube surfaces will impair boiler performance.

While soot blowers are normally provided to clean the external (gas side) surfaces using the action of steam or air jets, their beneficial effects do not occur automatically. Blower operation should be scheduled on a regular basis and operators can be trained in the use of hand-held air or steam lances to clear slag or ash accumulations not removed by normal operating cycles of the soot blowers. Maintenance of the water side surfaces is also essential to long tube life and high efficiency. Here, the keys are proper feedwater treatment and scheduling of blowdown rates.

Boiler blowdown — a necessary heat loss.

Blowdown, of course, is required because when boiler water is turned to steam, almost all of the solids stay behind, and the level of dissolved solids concentration in the drum water must be maintained below a maximum level set by the manufacturer. Unfortunately, blowdown not only removes solids, it removes hot water and if excessive can result in significant heat losses.

The amount of blowdown required is directly related to the solids concentration of the feedwater and, as a result, properly treated feedwater is critical in maintaining blowdown at a minimum level. Returning condensate (discussed later), since it is free of solids, can make a real contribution to minimizing blowdown — not to mention reducing fuel consumption and treatment costs that would otherwise be incurred by heating city water to temperatures appoaching the boiling point.

Where compressor cooling water has been softened or treated as boiler feedwater, it too can make a significant contribution to reducing blowdown.

Some level of blowdown, however, must be accepted and continuous rather than periodic blowdown is preferable from the standpoint of controlling the associated heat loss. In addition, boiler water conditions should be checked twice each shift by a chemical analysis of the chloride content or by conductivity measurements.

Even if boiler blowdown is reasonably small, heat loss can be minimized using a blowdown heat exchanger or a blowdown flash tank.

A heat exchanger recovery system involves first the recovery of heat in the blowdown using a heat exchanger to preheat makeup water before it enters the boiler feedwater heater. In addition, a portion of the boiler blowdown is recovered as flash steam for use in the feedwater heater or for low pressure process or heating use.

The quantity of heat recovered in the heat exchanger can be calculated by a basic thermal balance analysis using the boiler blowdown rate, the characteristics of the heat exchanger and the temperature of the blowdown water — along with the average city water make-up rate and temperature.

The quantity of steam recoverable in the flash tank, on the other hand, is a function of the conditions of the blowdown water and the pressure of the flash tank. A chart is included which allows calculation of the percentage of liquid likely to be flashed to steam.

Another possibility for improving the efficiency of a boiler is to reduce the temperature of the flue gas leaving the boiler by using an air heater or economizer. The latter is a tubular heat exchanger used to cool boiler exhaust gases by heating the boiler feedwater. Many large utility boilers use both an economizer and an air heater, whereas in small industrial boilers one or the other but rarely both are found.

It is also worth mentioning that economizers are not normally used in low pressure boilers because the temperature difference between the feedwater entering the economizer and stack gases (200°F feedwater — 500°F gas) is less than the temperature difference for an air heater (80°F air — 500 or so °F gas). An exception here are stoker fired boilers where ash problems and requirements to use combustion air to cool grates generally dictate the use of an economizer rather than an air heater.

After the boiler, heat containment is the challenge.

As soon as steam leaves the boiler, it immediately begins to try and give up its heat. The job facing an efficient system, then, is to assure that as little heat as possible is lost before the steam reaches the point at which the heat is needed.

In this regard, the first essential is that there should be no heat lost through direct steam

How much do leaks cost?

Size of leak (inches)	Air		Steam	
	Loss Per Month Cu. Ft. at 70 Psi. G.	Cost Per Month $ at $0.15/1000Cu. Ft.	Loss Per Month Lbs. at 100 Psi. G.	Cost Per Month $ at $3.25/1000 Lbs.
½	13,450,000	$2,020	500,000	$1,600
¼	3,360,000	$500	175,000	$570
⅛	840,000	$130	45,000	$150
1/16	210,000	$30	17,000	$60
1/32	50,000	$8	1,000	$30

leakage from faulty valves and joints. This kind of waste is both easy to detect and quick to consume energy and dollars. The chart gives estimates of the volume of steam that can be lost through holes of various sizes, but one graphic example is that in a 100 psig system, the steam leaking through a 1/32-inch hole will cost your company about $360 per year.

A considerable amount of heat can also be lost due to radiation from uninsulated steam pipes, and the facts here are even more staggering. A 10-foot length of uncovered 6-inch pipe carrying steam at 1-100 psig can waste 5 tons of coal or more than 650 gallons of oil a year. And it doesn't take a computer to see that a $300 or more loss can be compounded many times over by the longer length of pipe in a plant.

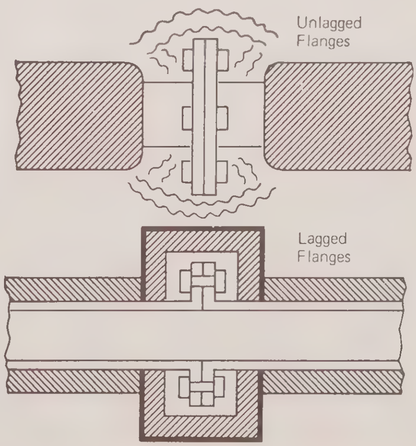
Many plants have insulated steam pipes over the years, but still experienced significant steam losses — whether they realized it or not. The source? — uninsulated pipe flanges. In fact, in many applications it has been common practice to stop an re-start the insulation 3 or 4 inches on either side of the flanges. There was an obvious reason for this practice — it made it easy to get at the flanges. But it should be recognized that uninsulated flanges are a source of considerable heat loss.

A ballpark assessment is that an uncovered flange represents the equivalent of leaving 2 feet of piping uninsulated. In other words, if 5 flanges are left uncovered on the 6-inch 100 psig line just mentioned, the equivalent of 350 gallons of oil is being wasted. The remedy? As shown in the diagram, flanges should be box insulated.

Nor does the problem of radiant heat loss stop there. Drying cylinders, steam chests, calender beds — in fact any process equipment where radiant loss is possible represent major consumers of energy. The rule of thumb here is that every square foot of uninsulated steam heated surface means, at 100 psig, a loss of about 820 Btu or approximately one lb. of steam per hour.

And the heat loss doesn't stop there. Heat from machines can make working conditions very uncomfortable, with the result that the operator opens a window to cool the shop. During the winter a cold draft blows over the machines and further increases heat loss.

Heat loss through unlagged flanges



Because of irregular shapes, not all process equipment is easily insulated—particularly where the equipment needs to be dismantled for maintenance on a regular basis. Insulation is, however, in a variety of forms and methods of application to enable both fitting of unusually shaped equipment and easy removal and replacement when required. A check with an insulation manufacturer or contractor will generally provide a solution to the problem.

In the rare case where equipment can not be effectively insulated without impairing some aspect of production or maintenance, aluminum paint is available that will give some protection against heat loss.

Why make steam work so hard?

Another major cause of energy wastage involves steam being made to do work which is unnecessary. Another booklet in this series ("How To Save Money Through Production Optimization") describes this situation in greater detail, and perhaps it is sufficient to say that in an ideal situation the plant should be shut down when not required.

Obviously, no plant will ever achieve a situation when the steam system is 100 percent utilized all the time, but to achieve real savings, it's a goal to shoot for. For example, a plant using 2,000 pounds of steam an hour, eight hours a day, five days a week when only 50 percent loaded wastes about 13,800 gallons of oil a year. That's $6,000 or more going up the flue.

Annual cost of heat losses from uninsulated steam pipes

Pipe size (in.)	Annual cost* (dollars)
½	300
1	1100
1½	1550
2	2050
3	2500
4	3650
6	4550
8	5650
10	7300
12	8500

*Note: cost per 100 feet of bare pipe.

Re-arrangement of process equipment, without interfering with production sequences can also pay handsome dividends by reducing steam loss—and the demand for steam—caused by straggling steam lines which have grown "like Topsy" over the years. The rule that equipment should be grouped as close as possible to the steam main is proven by the fact that even an unnecessary 10 feet of 2-inch pipe can waste $30 to $40 of fuel a year in a plant operating 8 hours per day, 5 days a week. This amount can be quadrupled for a plant which operates around the clock seven days a week. Insulation will, of course, reduce the loss by 70 to 75 percent, but it can not eliminate completely the waste caused by unnecessarily long steam distribution lines.

In this regard, splitting up the distribution system with suitable isolation valves will help, for example, by allowing one section of the factory to work overtime without maintaining steam in the pipes to other departments.

Another means of reducing the work to be done by steam is dealt with at greater length in the "Process Design" booklet in this series. In essence it involves making sure that processes are not operated at temperatures greater than those required to do the job well.

To cite an example, five open process tanks were operating at a temperature of 180°F, when it was known that 150°F would really do. The waste involved was an extra 11,500 gallons of fuel oil a year—more than $5,000 down the drain every year that could have been eliminated by a one time expenditure of less than $2,000 on temperature control equipment.

Lower pressures where possible.

It's a physical fact (and one readily determined by a quick look at one of the steam tables in this booklet) that the latent heat of steam decreases as the pressure rises. This means that the higher the steam pressure, the smaller the amount of latent heat (the most readily available heat) that will be available per pound of steam. Conversely, more pounds of steam at a higher pressure are needed to supply a given quantity of heat.

From the standpoint of steam economy, then, the lower the steam pressure, the lower the steam consumption for a given amount of heat

required. In addition, losses from leaks and traps will be lower. So it should pay to reduce the pressure in a steam system. And it does. There is an example in the case history of this booklet of a Canadian company which has done just this and saved dollars as a result.

The only bump in this otherwise smooth road to energy savings is that the lower the steam pressure, the lower is the temperature and, therefore, the lower the rate of heat flow from a given surface are (even though losses will be lower). Obviously what is called for under the circumstances, if pressure is to be lowered (or kept at the same rate and more work accomplished in a shorter time through greater heat available) is higher heat transfer in process equipment or any steam / heat exchange application.

On occasions, the amount of heating surface can be increased. For example, in heating system working at a pressure of 80 psig, by increasing the heating surface by 25 percent. In a room with four lengths of heating pipe, this would mean another length of pipe would be required. The resulting savings in energy use would average 4 percent per year.

Increasing the heating surface is a principle which should be borne in mind particularly when designing steam heating systems and when fitting heating coils in process tanks. But on a "retrofit" basis, in most process applications there is no opportunity to increase the heating surface. In these cases, the only avenue to improve steam efficiency at the extreme end of the system—and perhaps to allow a reduction in steam pressure—is a reduction of films and other barriers to effective heat transfer.

The diagram is very important in that it shows schematically the heating surface on any process steam application where the steam does not come into direct contact with the material being heated.

On the water side there is a stagnant film of the product (in this case water) and possibly a scale film of caked on product. These put up considerable resistance to the flow of heat to the product, but the effect of both can be negated quite successfully by regular cleaning or by mechanical stirring. Both are recommended and will pay dollar benefits.

Air-heat transfer's greatest enemy.

But where the problem is most severe and difficult to control is on the other side of the metal wall, on the steam side. Here there are three films: first, there is generally a scale film made up of rust and dirt from the pipes and of impurities carried from the boiler by the steam where feedwater treatment is not satisfactory or the boiler is under heavy load conditions. A periodic cleaning of this surface, regularly if possible, will reap tremendous improvement in heating efficiency.

Secondly, between the steam and the heating surface there are typically two more films. One of them is a water film—and water is a poor heat conductor. The other is an air film and represents the major barrier to good heat transfer.

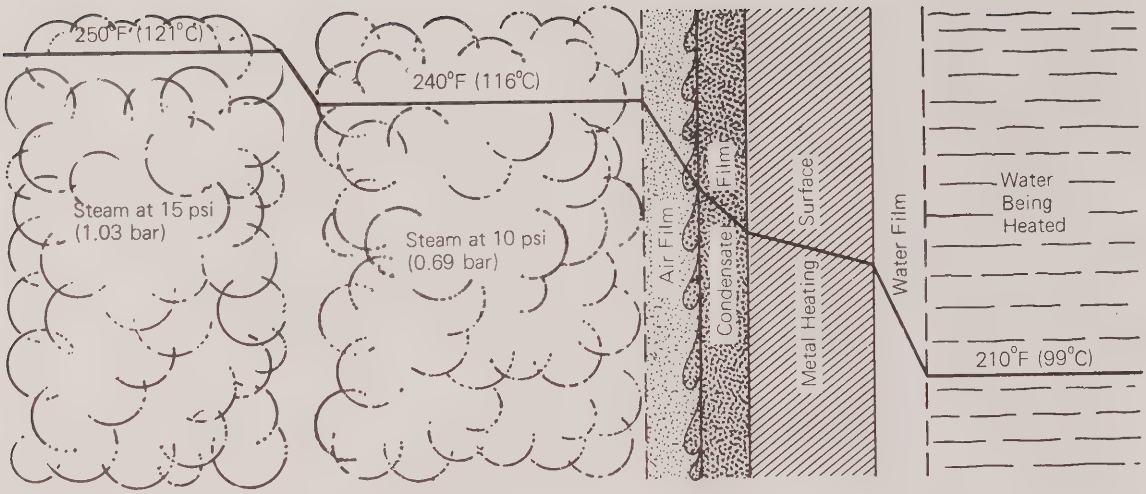
Water is bad enough. It is between 60 and 70 times more resistant to heat transfer than the iron or steel wall of the heating surface and 500 to 600 times more resistant than copper.

But given that among insulating materials the most effective insulator is the mass of minute air cells enclosed by non-conducting fibres, it should come as no surprise to learn that air is more than 1,500 times more resistant to heat transfer than iron or steel and no less than 13,000 times more resistant than copper. This means that a film of air only 1 / 1000 inch thick will resist heat transfer as effectively as a wall of copper 13 inches thick!

The practical effect of air and water films on process output is shown in the diagram. By reducing the thickness of the air and water films, steam pressure can be reduced a full third from 15 psig to 10 psig while still achieving the same required process temperature of 210°F.

Obviously, on all process applications, the thickness of the films on the condensing surfaces must be reduced. In fact, in the case of the air film, a number of other problems other than reducing heat transfer result. Air causes a reduction in steam temperature below that of undiluted steam and can gather in pockets in process equipment where the cross section of the steam space is realtively small — and as a result cause cost spots on the heating surface.

All of these problems eat into the efficiency of the



The effect of air and water films on heat transfer

plant equipment and, in the end, increase energy consumption.

The solution? For the air film the answer can be use of balanced pressure air vents which have a thermostatic characteristic which allows air steam mixtures to escape but which close in the presence of steam and are not affected by variations in steam pressure. Although some companies have encountered maintenance problems and eventual steam leaks. As a maxim: "A good trap will remove air in a well designed system".

Because the position of the steam inlet and the shape of the steam space have an important bearing on where air will be deposited, it is not possible to lay down any hard and fast rules about the positioning of air vents. A knowledge of the shape of the steam space and a number of other factors will help, and a consultant or supplier will certainly be able to provide needed answers. The choice of steam traps based on ability to handle air may also be involved.

Water — a difficult foe.

The challenge with the condensate or water film is one of a different order. When "dry" steam comes into contact with the surface to be heated, it gives up its latent heat and condenses — forming the insulating film. If the steam is wet, that is, contains fine droplets of water, this water is deposited on the heating surface, increasing the insulating film but contributing nothing in the way of latent heat.

The fundamental solution is to improve the dryness factor of the steam as it leaves the boiler, by eliminating peak demands and overloading of boilers where possible, and by careful attention not only to boiler treatment chemicals but to the way they are applied.

However, the very nature of steam generation under commercial conditions makes it impractical to avoid some carry over of water particles in steam — and more water is necessarily added by the steam as it passes through the pipe system.

Here, it is critical that steam be taken at the top of the main line and if the line is well drained, dry steam should be available. In any heat exchanger, the slope of the pipe will be critical in eliminating water quickly.

Steam traps — a culprit that needs attention.

It's no news that when steam gives up its latent heat, it condenses and must be removed from the lines using steam traps, to allow steam to make good contact from heating surfaces.

One case history in this booklet deals in some depth with an organized approach to steam trap maintenance and will be of interest to anyone who wishes to pursue the subject in greater depth. Suffice it to say, selection of the right steam trap and locating it in the best position is important as is the use of strainers in front of the traps to prevent accumulating of dirt and foreign material in the traps themselves — a leading cause of traps "blowing steam".

Sight glasses in the line after the traps can be useful in detecting leaking steam traps, and thermal tapes which change colour at temperatures above the condensate temperature can be of assistance, but the operative word as far as energy conservation through steam trapping goes, is *MAINTENANCE* — regular inspection of steam traps and replacement where necessary will pay for itself every time and should be a major priority in every plant with a steam system.

The condensate, which is collected by steam traps along the line, still contains a significant amount of sensible heat and if simply directed to the sewer, will carry a significant amount of heat and dollars with it. Some plants manage to recover more than 90 percent of this condensate as boiler feedwater. For these plants, it represents a source of hot, pretreated water. In short, it's a valuable commodity.

In many cases these plants are in areas where there is not an abundance of fresh water. The energy that was being wasted was really not a factor. As a result, many other plants where water is available, have a very low recovery of condensate. But the ground rules have changed over the past few years and given today's energy economics, it simply makes sense to maximize the recovery of condensate as boiler feedwater.

But before condensate can be used for this purpose, it must be discharged from the steam line to the lower pressure of the condensate return line. And high temperature condensate can not completely remain as water — the excess heat allowed by pressure re-enters the water as latent heat forming "flash" steam.

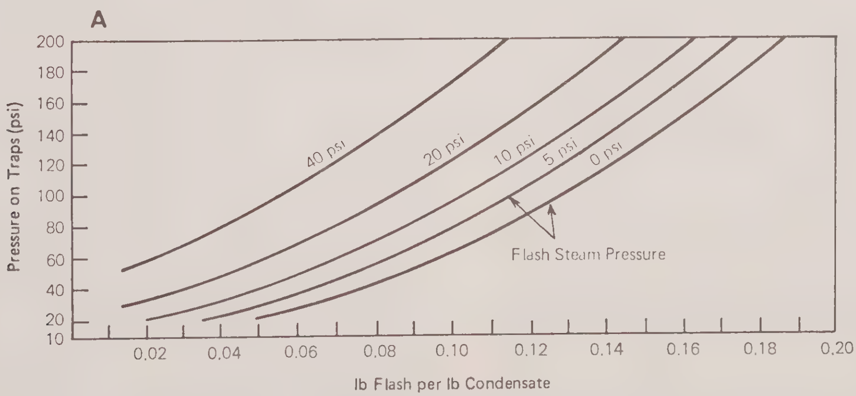
If the condensate is collected in a return line at atmospheric pressure, the flash steam will generally condense, forming condensate at 212°F, but the latent heat of the flash steam will have been wasted.

However, if the condensate can be discharged to equipment merely working at a lower pressure, much of the flash steam can be recovered and put to use. The chart on this page shows the amount of flash steam generated when condensate at different pressures is discharged to a heating or process system at a given pressure. For example, when condensate at a pressure of 200 psi is discharged into a 10 psi system, flash steam amounting to 16 percent of the condensate will be found.

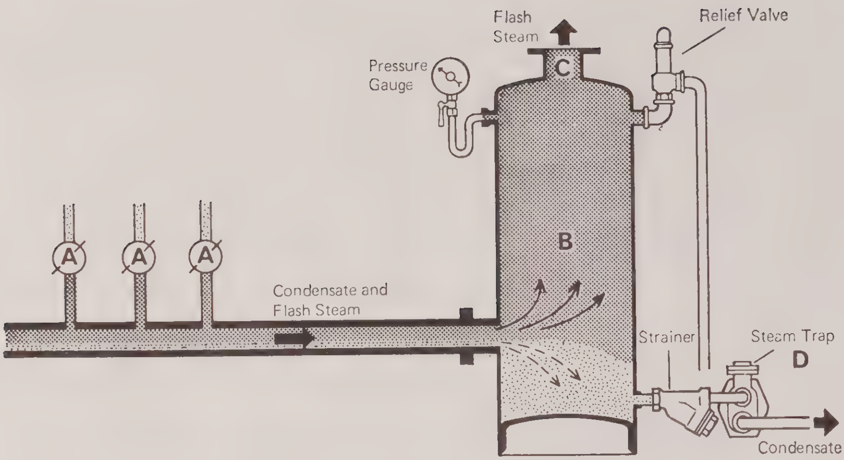
Flash steam and condensate recovery-related subjects.

In most industrial applications, condensate from various pieces of equipment is discharged into a common condensate line back to the boiler feed tank. The condensate pipes are often not insulated and the feed tank uncovered or sometimes an open tank vented to the atmosphere, with condensation return delivered above water level.

Flash steam formed at traps travels with the condensate along these return lines. If the pipes are uninsulated, much of the steam will condense as outlined before, and the heat will be radiated to the air. If the pipes are insulated, a good deal of steam will reach the tank and if the condensate return is above water level, much of the flash will escape to the air. If the return is below the water level and there is a considerable proportion of cold make-up water, some of the flash will be condensed and the temperature of the feed raised.



Quantity of flash steam available at various operating conditions



A typical flash vessel in operation

If all precautions have been taken to conserve heat in the condensate, a major question must be asked. Will the feed pumps handle water at the high temperatures involved? In most situations, the better solution is to put a flash vessel either in the common condensate return line or in after the traps on large high pressure steam using equipment. The flash steam given off here can then be taken to a low pressure steam system or unit.

As shown in the diagram, condensate at high pressure passes through the traps to the flash vessel which is at a lower pressure so that some of the condensate flashes to steam as it leaves the traps. The flash steam is led away and the condensate drained by a float type trap with continuous discharge.

Under the ideal circumstances, flash steam should be used where there is a continuous demand for all the flash steam available and where maximum heat recovery can be attained by keeping pipework to a minimum. This generally leads to a number of small self-contained recovery units rather than one large unit. And obviously, both the flash unit and connecting pipes should be well insulated.

Heating systems often offer good opportunities to take advantage of low pressure flash steam. The hitch is that while low pressure steam has a higher latent heat content, it also has a lower temperature (total heat content) requiring larger pipes, unit heaters and other heating surfaces.

Generally, the most happy solution is to use a combination of high and low pressure steam for heating. If a plant consists of, say, five bays, it makes good sense to heat four bays with high pressure steam from which flash steam is recovered to serve the fifth bay at low pressure.

However, there are many process uses for low pressure steam as well, and it is well worth while to look for them around the plant. Use of low pressure flash steam can considerably reduce demands on the main boiler and in so doing, save considerable amounts of fuel and dollars. In some cases, it can even do away with the need for additional main boiler capacity. Much written material is available to help with such factors as flash steam pressure and the size of the flash vessel. A consultant with specific expertise in the area may also be necessary. But whatever is done to recover flash steam, chances are it will be worth the investment.

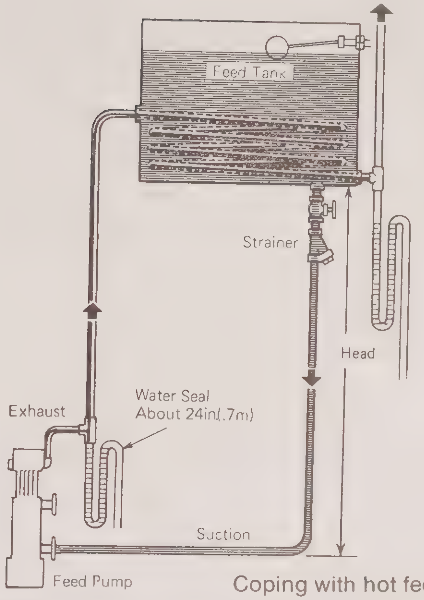
Condensate — too hot to handle?

It was mentioned earlier that without flash steam recovery, condensate could be too hot for pumps to handle in moving into the feedwater tanks. In those cases where sufficient static head does not exist over the pumps to handle the hot condensate, think of installing an auxiliary feed tank at a higher level. As shown in the drawing, condensate from the existing hot condensate tank can easily be raised to the new high level using a pumping trap — an automatic device in which a float, responding to the level of incoming condensate, opens a boiler pressure steam valve and flows a charge of condensate to the higher level. A pumping trap is not large and consumes very little steam.

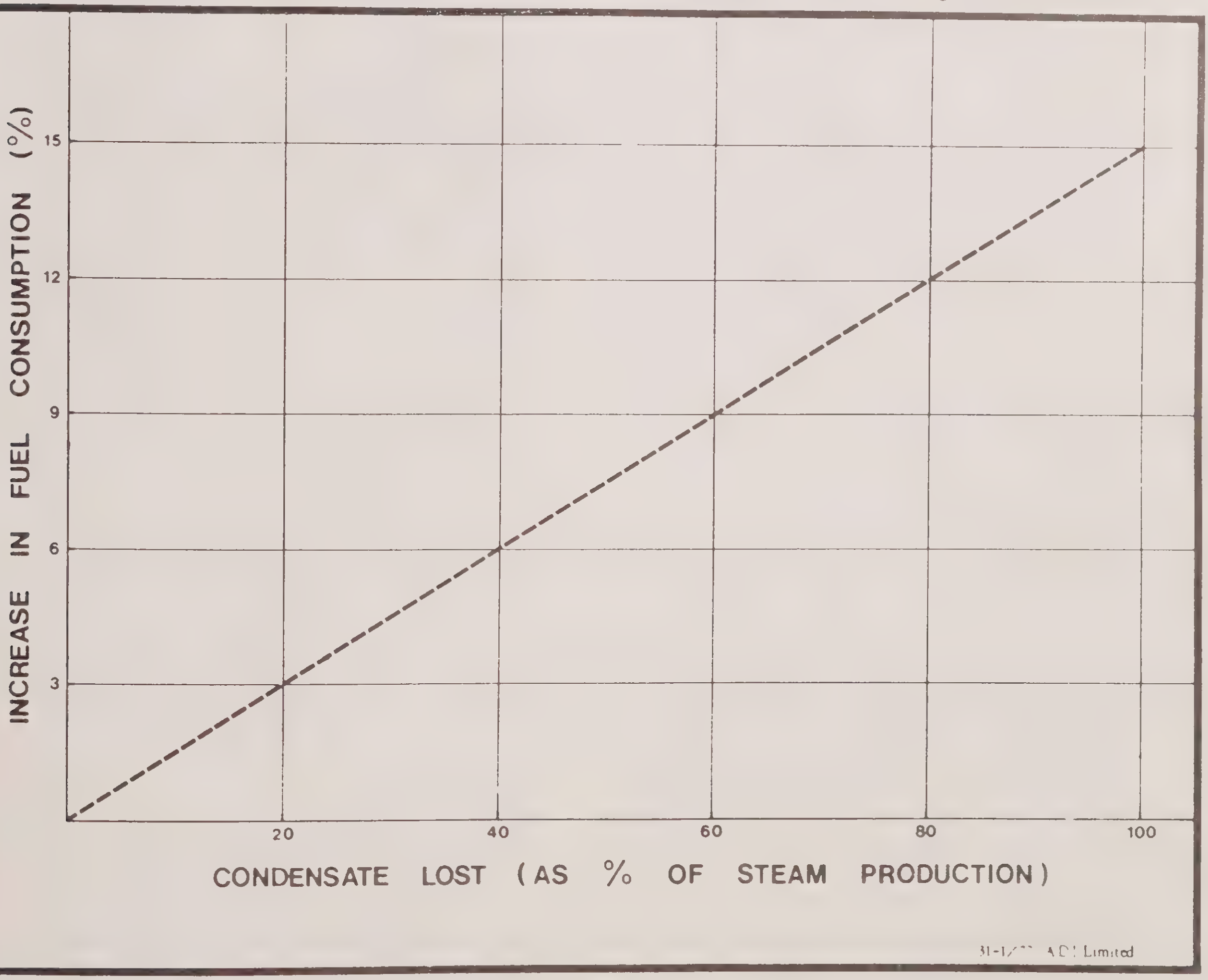
Condensate then can be handled by some means, whatever its temperature, when returned to the collection tank. But perhaps, some general comments are in order about the desirability of making sure that this condensate is captured and used as boiler feedwater. The graph plots percentage of condensate lost against the resulting increase in full consumption.

As a general rule, every 11°F rise in the temperature of the feedwater results in approximately 1 percent less fuel being burned in the boiler. And don't forget that to this saving must be added the economies derived from the reduction in water consumption and treatment chemicals or process requirements!

As mentioned earlier, condensate lines should be well insulated — as should the feed tank itself. In fact, both insulation on the bottom and sides of



Coping with hot feedwater



a tank and a cover are well worth the investment. The diagram demonstrates this point quite graphically.

Frequently, condensate is not returned to the process tank because it is thought that equipment is too far away. As a result, the economics appear, at first glance, to be poor. As with most energy conservation investments, this is generally a poor assumption to make. A careful analysis of the one-time costs versus the long term savings generated will almost always justify the cost of piping.

Other uses for condensate.

Even if the cost of returning condensate to the boiler should prove to be prohibitive, there is no point in disposing of it in the sewer. Washing or other processes can always use preheated clean water and will produce direct dollar savings comprised of both the cost of water and the energy which would have been necessary to heat it.

But the operative word in the preceding sentence was "clean". And it is essential that the condensate not be contaminated when it is returned to the boiler. Oil from engine exhausts, material from prcesses, iron from cold lime treated makeup water and a number of other contaminants can find their way into condensate. But there are ways to reduce this contamination. For example, repairing the break in steam coils will generally remove product contamination and neutralizing or filming amines injected into the steam will reduce iron pickup in the condensate return system.

But, again, if the economics of the operation do not justify the de-contamination of the feedwater (and this is rare), consider the heat value of the condensate and make use of it in some fashion. Send it to the sewer only as a very last resort.

To cite one possibility, a simple heat exchanger where a bath of hot (and perhaps corrosive) feedwater is used to heat feedwater running through a coil of pipes, can be an efficient low cost means of recovering heat from the condensate if it can be used for no other more profitable purpose.

Steam tracing — a savings opportunity.

It goes without saying that use of steam for tracing systems to prevent liquid piping from freezing in cold weather represents another important area which should be considered in planning an energy conservation programme for your plant. While the potential dollar savings are not as large because the volume and pressure of steam used is generally considerably lower, it is an area which deserves attention. And for the most part, techniques used in process and steam heating applications can be applied directly to steam tracing applications.

And maintenance is again the watchword.

As a basic assumption, winter tracing should not be used until necessary and should be turned off during the summer (it is surprising how many systems are left on through the hot weather). It goes without saying that traced lines should be equipped with appropriate traps and insulated as well as possible. Preventive maintenance on the traps and frequent checks to make sure that they are not "blowing steam" will also result in significant savings.

Perhaps two relatively new techniques warrant singling out for special mention. The first of these essentially displaces steam in tracing applications and can offer substantial savings on maintenance and fuel costs. It involves the use of a specially inhibited ethylene glycol/water solution — with a freezing point of $-34°F$ in place of steam to heat tracing lines. While these systems are only economically applicable in plants with major consumption of steam for tracing, they involve only one steam trap — on the heat exchanger which heats the solution in a tank before it is pumped through the tracing lines — and can achieve steam savings of 1,000 pounds per foot of tracers per year.

One plant in the United States cut its steam consumption for tracing in half by converting to an ethylene glycol heat transfer medium system. And although additional electricity was required to pump the solution through the pipes, the net savings was still in the neighbourhood of 40 percent — with the investment required for conversion almost entirely recovered in the first year of operation.

The second energy conservation measure is nothing new in concept. It involves the shutting off of steam to tracers during weather where steam is not required. The difference here is that it can be done automatically by a temperature activated control valve which opens fully at

atmospheric temperatures under 34°F and fully closes at temperatures over 40°F. These valves are a low cost substitute for temperature control loops and should be explored as a means of reducing steam use — and saving dollars — on tracing systems.

Look for more information.

The economics of steam and steam savings are further dealt with in the case history section. Hopefully, the total effect will be to make steam users aware of, or remind them of, the major opportunities that exist for energy and dollar savings through boiler efficiency, boiler heat recovery, insulation, reduction of steam requirements, flash steam and condensate recovery, preheating boiler makeup water with cooling water from welders, cooling towers, compressors, etc. . . . the list goes on and on.

The opportunities are there for the taking. There are no physical barriers. If the barrier to better steam usage is bureaucratic or organizational — that is, if steam generation is the responsibility of the plant engineer or plant engineering department, and steam usage the responsibility of production departments . . . and the two cannot get together on the situation — sort it out. The savings will be worth the mild diplomacy (or head knocking) required.

Compressed air management

Over the past years, tremendous strides have been made in the development of advanced air operated devices and tools for a variety of industrial applications. But efficient as they are, these new tools cannot be viewed in isolation. They are part of an overall compressed air system within the plant — and are only as efficient as the power that drives them.

Yet in many plants, compressed air systems do not get the attention they deserve. These neglected systems waste compressed air, consume much more energy than is required, and cause air tool and hoist operators to take longer to do their jobs.

Compressed air is an obvious and very visible segment of your plant's operations to select as a priority for an energy conservation programme. It represents a valuable commodity whose use and efficiency can be relatively easily monitored and one which will show immediate and substantial savings in fuel bills as a result of enlightened energy conservation practices. In short, it's one of a number of good places to roll up sleeves and "start" on energy conservation once the basic housekeeping energy chores have been completed.

It is general practice in industry to express compressed air capacity as the flow at atmospheric pressure — the so-called "free air flow" — to avoid the burden of re-stating actual pressure for each application. But as any plant engineer who monitors his power bills knows, compressed air is anything but free.

And as the cost of energy continues to climb, compressed air will become an even more precious commodity.

For example, assuming a compressed air supply of 100 psig, at least one kilowatt of installed motive power is required to provide a "free" air flow of six cubic feet per minute. Assuming the cost of electricity at 2.5 cents per kilowatt-hour (Kwh), and a factory a 48-hour week or 2,400 hours per year, the energy costs of compressing 1,000 cfm amount to more than $10,000 per year. This is a large-scale example; but in any plant if savings can be accomplished with little or no extra expenditure, even a ten percent reduction in energy use, due to improved efficiency of the system, can make a very worthwhile contribution to the company's "bottom line".

And as the flow and pressure of compressed air and the cost of energy increase, the savings become even more dramatic. As an eye opener, why not do a thumbnail analysis of your plant's compressed air consumption? Assuming an arbitrary level of energy reduction, the potential savings will probably surprise you.

Where can energy be saved?

There are a number of ways in which both compressed air and energy — and dollars — can be saved. They range from simple adjustments (for example, lowering the pressure in the plant system from an arbitrary or historic level to what is actually required to run equipment) . . . to basic maintenance such as repairing leaks in compressed air lines . . . to more costly steps such as replacing inefficient air compressors with newer models offering better fuel efficiency, improved air quality and greater overall savings.

For the sake of the analysis, the area can be divided into six components:

1. Selection of compressors.
2. Optimum compressor utilization.
3. Avoiding leaks and other wastage.
4. Efficient running of air driven equipment.
5. Lower pressure on the system.
6. Recovering the heat of compression.

These topic areas are not arranged in any order of priority based on the relative complexity or capital investment requirements to carry out the work. However, they are hopefully presented in a logical fashion that will enable the plant manager or anyone else responsible for compressed air to apply some basic ideas to reduction or energy consumption on industrial compressed air systems.

Certainly, before maximum use can be made of the information presented, the reader will have to understand the nature of his compressed air system and eventually carry out an "audit" of its efficiency. The subject of energy audits is covered fully in the introductory handbook in this series.

1) Selection of Compressors.

Most of the comments in the compressed air section apply to the operation of existing systems, but at the outset it is worth mentioning a number of factors which can be borne in mind when selecting a compressor or group of compressors for a new industrial application or replacement of an existing unit.

Prime among these, is the question of a large central installation versus several smaller separate compressors located nearer to the point of end use. What is best for a given plant will depend on the flow rate required, the physical layout of the plant, how the compressed air is used and the length of daily and weekly periods for which compressed air is used.

However, under the right conditions — and as a basic rule of thumb, 500 cfm appears to be a minimum flow level to derive real benefits — the use of smaller compressors each operating at a higher overall level of efficiency can offer significant benefits in energy and dollar savings, among them:

- unit selection in terms of size is less critical. Later modules can easily be added if budgets are tight. Less engineering and evaluation is often required to evaluate the plant's needs.
- initial capital cost is lower. In buying a single unit, there is often a tendency to "be conservative" and buy a unit which is really too big. A large compressor running "underloaded" much of the time is considerably less energy-efficient than a number of smaller machines running at their designed load.
- with multiple air cooled compressor units distributed throughout the plant, it may be easier and more economical to recover waste heat to take some of the load off plant heating units in the winter. (However, a large water cooled central unit could well improve the economics of recovery of coolant as water for washing operations or boiler feedwater.)

Certainly, each smaller compressor in each zone has to handle peak demands . . . and if the zone peaks don't coincide, a central installation where efficient use is made of the horsepower available may be preferable.

The selection of a type of compressor suited to the specific requirements of the plant can also have a significant effect on energy conservation. And one of the factors that should go into discussions with manufacturers is the potential for waste heat recovery from both air and water-cooled machines.

Multi-stage compression and other more esoteric machines can offer greater energy savings. While in many cases these machines entail a higher initial capital expenditure, an economic evaluation at the time of purchase may show that energy savings from one type of compressor are a critical factor in unit specification. As a basic rule: choose the compressor with the highest ratio of cfm delivered to brake horsepower.

2) Optimum Compressor Utilization.

Efficient operation of compressors is fundamental to the energy efficiency of the system. And the first step in the system involves the availability of suitable intake air for the compressor. Not surprisingly, cool clean dry intake air leads to more efficient compression and a sheltered inlet protected from rain on a

north wall is an ideal intake location — with ducting between the intake and compressor short, straight and of sufficient diameter. Dust in the system clogs filters and wastes energy.

As an indication of the savings that are possible by controlling intake air conditions, it is worth remembering that for every 10 inches of pressure lost at the inlet, compressor performance is reduced by two percent. Similarly, a 7°F rise in inlet temperature results in a 1 percent rise in energy consumption to achieve an equivalent output.

Compressor maintenance — a critical factor

Once it has been established that the compressor is receiving an air supply of sufficient quality, a critical factor becomes maintenance of the compressor itself. Perhaps the best advice that can be given here — although it seems obvious — is to follow the manufacturer's instructions to the letter. In the end, it will lead to maintained rated performance and optimum thermal efficiency.

Among the most critical items which should be checked are:

- tightness of driving belts.
- valve gear, pistons and piston rings on reciprocating compressors.
- vanes on rotary compressors.
- blades of turbo compressors.

The same principles apply to intercoolers and aftercoolers which reduce the amount of both oil moisture in compressed air. Here, it is critical that water cooling ducts are not scaled or blocked and regular draining provides an excellent opportunity to check and control this problem.

One additional means of increasing energy efficiency involves the use of generous sized receivers (larger than the usual 1-1.5 cf per 10 cfm). These can be a means of accommodating increased air requirements or high peak demands from an existing smaller compressor—with correspondingly low energy use. At points of sudden high demand in the system, an extra receiver near the point of take-off may avoid the need to provide extra capacity, and will save energy as a result. As a final step, a control system will help ensure efficiency of the compressor and thus its energy consumption. It can also assure that significant periods of off-load running do not occur and that an excessive number of stops and starts — both significant energy wasters — do not occur.

Basic instrumentation includes a pressure gauge on the receiver, water temperature gauges on the compressor cooling jacket and the aftercooler (in the case of water cooling) and air temperature gauges at the outlet of the compressor and in the receiver. Pressure gauges at selected points along the airline system will also indicate the effectiveness of the system and should be logged regularly along with other pertinent data to provide a record of efficiency.

While much can be done to upgrade energy efficiency without resorting to sophisticated control systems, the latter can offer significant savings — particularly by most efficiently balancing the load between compressors where two (lead and standby) or more are being used.

Keeping air dry can produce energy savings.

One of the parallels that exists between steam and compressed air operations is that both operate more efficiently without water in the distribution system.

With compressors, water enters as vapor along with air. In fact, under conditions of 75°F and 75 percent relative humidity, a 100 cfm compressor will take in about 18 gallons of water per day in the form of vapor. And about 90 percent of this water condenses during compression and winds up as a liquid in the aftercooler and piping system.

Water, or the sludge formed by the combination of compressor lube oil and water, corrodes the inside of air pipes, increasing internal resistance and building up a pressure drop that wastes power. The reduced air pressure reduces the efficiency of air tools. Just as importantly, corrosion pits and pockets can weaken the pipe and cause leakage at valves, joints and traps. Water in air systems can cause a multitude of other problems as well, but in general they all result in reduced productivity and energy efficiency.

The solution—refrigerated or chilled air dryers available from a number of manufacturers.

3) Avoiding leaks and other wastage.

The objective of a distribution system is to carry compressed air from the compressor to the tool or other powered equipment with the minimum pressure loss. And as a guide, a well laid out and maintained 100 psig system should deliver air to the point of use at close to 90 psig.

To make sure that the system is operating efficiently, it is imperative to record air pressure frequently during periods of heavy use—simultaneously listing pressures at the end of branches and at individual tools when they are running. Pressures recorded at the receiver and branch ends should not differ by more than 5-7 psig. If they do, chances are your company is wasting more in energy and production dollars than the cost of a revamping of the complete air system. And the effect on production of pressure loss is a dramatic and easily quantifiable one—a drop of 10 psig at the tool inlet reduces its available power by 14 percent. A drop of 30 psig can affect tool performance by as much as 55 percent—and drastically increase energy use per unit of production.

Branches, hoses, couplings—an opportunity area.

It is important to remember that the main air lines and associated branches, hoses, couplings and other accessories offer considerable opportunities for energy conservation. And among the ways to reduce pressure drop and leakage—and increase energy efficiency—are the following:

- use long radius bend and welded joints wherever possible in piping.
- incorporate strainers and lubricators for each air operated device.
- avoid condensed moisture buildup by sloping piping to strategically located drain legs equipped with automatically operated valves.

However, almost without exception, the largest single pressure loss in any compressed air system is found in the hose and its connection to the tool. For example, a system with 100 psig at the compressor receiver should produce 94-95 psig at the hose entrance—allowing for a 4-5 psig loss in the hose (proper hose selection can minimize that loss). A check with the manufacturer will assure that hoses are the right size and length to give proper throttle pressure and power at the equipment.

Pressure loss also frequently results from friction in piping. As a rule, the smaller and longer the pipe, the greater the friction. And shortening the length of pipe and reducing flow restrictions are both available remedies. The third major means of reducing pressure drop in the system is to reduce the velocity, or flow rate, of air through the system. For the main distribution line from the compressor installation, excessive energy loss can be avoided by restricting the air velocity to a maximum of 1,200 ft./min. Higher velocities are allowable in shorter branch lines of total lengths of less than 50 feet. Bear in mind, however, that reduction in velocity may entail installation of auxiliary receivers at points of heavy load.

Line loss through leakage can also represent a major energy—and dollar drain. Leaks occur frequently at air receiver relief valves, pipe and hose joints, shut-off valves, quick release couplings, tools and equipment. In extreme cases, compressed air leaks will account for 20 percent wastage in compressor capacity. Ten percent of capacity is commonplace.

Air leaks seem insignificant, and to be fair, they usually are caused by a large number of small openings. But the total effect adds up to a major energy loss, the solution to which problem can again be stated in one word—maintenance.

In this case, maintenance means regularly inspecting the steam packing valves in the system—repacking when necessary . . . replacing leaking shut-off valves and valves on equipment . . . in short, regularly inspecting lines for leaks and replacing faulty equipment. If your plant shuts down for Christmas or an annual holiday period, seize it as the ideal time to look for the small leaks that are almost impossible to hear over the noise of plant equipment. It's the time to carry out a blitz campaign—followed up by a year-round maintenance programme.

To make a ballpark estimate of the magnitude of the total line leaks before going ahead with a programme, one simple method is available which makes use of the known free air delivery capacity of the compressor and an ordinary watch.

With all air operated equipment shut off, run the air compressor until the system reaches full line

pressure and the compressor unloads, note the time. Due to air leaks, the system pressure will fall, and the compressor will come on load again, note the time. The period for which the compressor is on load and off load should be recorded at least four times to give a mean value of each.

Let T minutes = Time 'on load'
Let t minutes = Time 'off load'
Let Q = Delivered free air capacity of compressor in cubic feet/minute
Let L = Total system leakage in cubic feet free air per minute

$$L = \frac{Q \times T}{(T + t)} \text{ cfm}$$

Power wasted $\frac{L}{6}$ kW

Leaking air means leaking dollars (see chart in "Steam" section). So instead of a "hiss", try to think of the sound of rustling dollar bills — it may act as more of a motivator to put the system in good order.

4) Efficient running of air driven equipment.

Air powered equipment represents the final link in the air compression system and it goes without saying that unless pneumatic tools, directional control valves and cylinders and other equipment are supplied with properly conditioned compressed air, wear of seals and other moving parts will occur — leading inevitably to a loss in operating efficiency with possible leakage of compressed air and energy wastage.

Here, it is equally important that a properly planned maintenance programme be carried out — not only for the air operated equipment, but also for the "conditioning units", filters, pressure regulators and lubricators which service the tools and cylinders to keep the system operating at maximum efficiency and using the minimum amount of energy.

To remove pipe scale, water and compressor oil, which can combine to form highly abrasive compounds, filters should be located as close as possible to the equipment consuming the air.

They should also be serviced regularly to clean or renew the elements which gradually become choked with dirt, causing excessive pressure drip and energy wastage.

The degree of filtration should be related to the application. The finer the pore size of the filter, the more dirt it will collect and the more readily it will become chocked.

In the case of pneumatic instrumentation measuring equipment and other applications requiring extremely clean air, it may be necessary to consider ultra high efficiency filters to remove all traces of water and oil droplets. These specialized filters can easily cause excessive pressure drop if allowed to become choked with dirt, and it is advisable not only to protect against excessive dirt contamination by using pre-filters, but also to continuously monitor the pressure drop so that action can be taken when this pressure drop exceeds the maker's recommended level.

Equipment should also not be operated above its recommended operating pressure. This not only wastes energy, and leads to excessive wear with further energy wastage — it is dangerous.

In certain cases such as ejection nozzles, where air is discharged direct to atmosphere for the purposes of cleaning or cooling operation at high pressure not only causes excessive energy wastage — a ¼ in. nozzle at 100 psig, can waste energy at the rate of 15 Kw. The pressure to the nozzles should be reduced to a safe and economic level or in the case of cooling air fed by low pressure blowers or fans. Alternatively, devices converting a small flow of high pressure air into a large flow of low pressure air will soon pay for themselves on cooling or similar applications.

Careful attention should also be paid to the lubrication of pneumatic equipment by installing properly designed lubricating equipment and not depending upon an operator disconnecting a hose joint and injecting oil from a can.

The lubrication equipment should also be properly maintained and replenished with clean oil. In addition to reducing friction and thus reducing energy consumption, proper lubrication will prevent wear of seals and other rubbing parts and thus prevent energy wastage due to excessive air consumption or leakage.

The following is a suggested checklist:

- cracked or worn hoses — replace.
- cracked drain cocks — close (Ideally replace by automatic drains).
- hissing couplings, pipe joints, valves — service, reset or replace.

5) Using lower pressure.

Assuming that "housekeeping" has been carried out and leaks have been reduced to a minimum, careful thought should be given to using lower air pressures — both by operating equipment at lower than line pressure and, particularly, where the maximum pressure output of the compressor can actually be reduced.

As the chart shows, the latter case offers a very substantial potential for energy savings:

Single stage			
Pressure (psig)	100	90	80
Power reduction	—	−4%	−9%
Two stage water cooled			
Pressure (psig)	100	90	80
Power reduction	—	−4%	−11%
Two stage air cooled			
Pressure (psig)	100	90	80
Power reduction	—	−2.6%	−6.5%

In many plants, a great deal of pneumatic equipment (spray guns, cooling jets, hoists, control systems, etc.) are operating at higher pressures than those recommended by the manufacturer. As a result, considerable energy is being needlessly consumed. For example, where a pressure regulator can be fitted on a fluctuating main line supply of 85-105 psig and pressures reduced to the optimum 80 psig for a particular piece of equipment, a full 14% energy saving can be realized. A further decrease to 70 psig, results in nearly a 24 percent saving.

Double acting air cylinders are also used in considerable numbers, especially on automatic and automated production plants and machinery, etc. Often a number of cylinders are only required to exert full power in one direction, the other direction being a simple return non-working stroke. In these cases considerable savings can be obtained by using a reduced pressure for the return stroke action.

For example, operating at 80 psig, a double air cylinder will, in general, function equally well using 20 psig reduced pressure for the return stroke and will reduce consumption to something like 68 percent (32 percent saving per cycle).

Similarly, use of remote receiver tanks close to cyclical loads can significantly improve the efficiency of production tools and may permit a reduction in line pressure.

A further reduction to 50 percent can be obtained by discharging the exhaust from the high pressure working end of the cylinder to a low pressure supply for the return and for other uses. Here, the auxiliary port valve is operated in combination with the main control valve so that on the return stroke, the high pressure exhaust is first directed to the reservoir and, as pressures equalize, the auxiliary valve is then reversed giving final exhaust action through the main control valve in the normal manner.

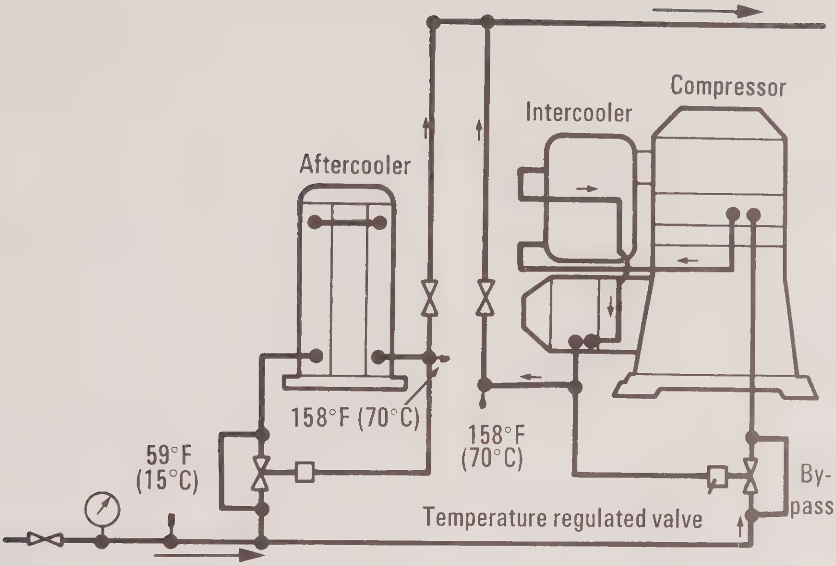
6) Recovering the heat of compression.

Since the energy used by a compressor is converted to heat, this is potentially the most rewarding area for energy savings. Practically all this energy can be made available for other purposes, and even a fractional percentage recovered represents a significant saving. Ideally, this should be considered when installing new equipment and discussions should be held with the compressor manufacturer at the time of selecting compression plant. However, there may be many existing points where hot air, water or oil — largely from various coolers — may be used.

In all standard air compressor installations, the major part of the energy put into the compressor by the electric motor is successfully re-extracted by compression stage cooling to maintain reasonable working temperatures by the intercooler to improve efficiency and by the aftercooler to remove moisture from the compressed air. The cooling medium is either water or air and the heat extracted is generally wasted.

For example, a 100 cfm compressor (26 hp) working at 100 psig can waste 65,000 Btu of heat per hour!

Frequently, compressors can be conveniently positioned to transport the heat to a location



A cooling water flow arrangement that offers good heat recovery and reduced cooling water consumption

where, for example, space heating is required. Temperatures of about 95-140°F above ambient air in the case of cooling water and 18-36°F in the case of cooling air, can generally be achieved. This is not always ideal for integrating with many heating systems, but the capital cost should always be balanced against the cost saving in space heating.

All compressor energy cannot be recovered, but with different arrangements, rather high efficiencies can be reached.

With water cooled compressors, most of the input energy can be recovered in the form of hot water and used for heating, as boiler feedwater, in wash and spray tanks and for other purposes.

With air cooled compressors, the hot air leaving the intercooler and the aftercooler can be ducted to an adjacent room and used for space heating, giving a recovery of up to 80 percent. To permit a constant room temperature also under varying compressor load, a recirculation flap valve should be used.

Summary:

Compressed air systems offer considerable potential for reduced energy consumption in most plant applications. As with the bulk of plant equipment, air compression must be seen as a *system,* and energy conservation activities approached in a systematic way.

The priorities of air management programmes in a given plant will depend on a host of local factors. But the necessity for a thorough, comprehensive approach — given the dollar savings that can be realized — do not.

Take a look at your compressed air system. Chances are, there's a good deal that can be done to improve its energy efficiency.

Air cooled compressor generates usable heat

The situation: Leigh Metal Products in London, Ontario were faced with replacing four smaller water cooled compressors which were both outdated and could not be counted on to deliver the full air capacity required for manufacturing.

Action taken: Given the choice of air and water cooled units, the company opted for a 40 h.p. screw-type compressor delivering 160-180 cfm. Leigh had already re-routed spot welder cooling water to the wash section of its metal preparation line and thus could make no use of compressor coolant from a water-cooled unit. They could, on the other hand, make use of the 100,000 or more Btu's/hr in heated air given off by the air-cooled compressor which, as it turned out, would be located next to the spray booth area — a cold spot in the plant and a continuing source of employee complaints. The compressor was installed and warm air ducted to the spray booth area during winter months and to atmosphere during the summer. The compressor was situated in a block wall enclosure to cut down on noise levels and to give better air control.

Energy savings: 100,000 + Btu/hr. In addition, cooling water consumption is eliminated.

Dollar savings: (Estimated) 100,000 Btu/hr × 2080 hrs/yr = 208 MMBtu/yr = 208 Mcf @ $2.00 = $516/year.

Cost of improvement: For ducting and labour $300.

Recommendation: Air-cooled compressor exhaust or heat from computer rooms should be considered a possible source of energy for space heating.

Automatic boiler tube cleaner conserves fuel

The situation: A container manufacturer realized that accumulation of soot on the surface of boiler tubes was acting as a thermal insulator and reducing the overall efficiency of the company's two boilers. The normal procedure had been to periodically (weekly or biweekly) shut down the boilers and manually clean each tube.

Action taken: The company implemented an automatic tube cleaning system in which each tube is cleaned at least every 30 minutes by adjustable timed blasts of compressed air. A catalyst is also automatically injected into the tube area to reduce soot and smoke emissions to the atmosphere.

Energy/dollar savings: This plant installed automatic tube cleaners on two fire tube boilers after year 2. One was rated at 400 hp (13.4 MBtu/hr), and the other at 500 hp (16.7 MBtu/hr). The following table shows actual fuel oil consumption and degree days for the year preceeding the installation and for two subsequent heating seasons.

Year	No. 6 Fuel Oil Consumption, gal.	Degree Day	Gal/degree-d
1	373,062	4,147	89.96
Automatic tube cleaner installed			
2	349,773	4,196	83.36
3	327,712	3,942	83.13

For years 2 and 3 heating seasons, the Average gal/degree-d
= (83.36 + 83.13)/2
= 83.25 gal/degree-d

Average percent savings in fuel with the automatic tube cleaner installed is:
Percent savings

$$= \frac{89.96 - 83.25}{89.96} \times 100\%$$

= 7.46%

Annual fuel savings
= 373,062 gal/yr × .0746
= 27,830 gal/year

Assuming the No. 6 fuel oil has a heating value of 152,000 Btu/U.S. gal;
Annual energy savings
= 152,000 Btu/gal × 27,830 gal/yr
= 4,230 MMBtu/yr

Based on a fuel oil cost of \$0.30 per U.S. gallon;
Annual cost savings
= 27,830 gal/yr × 0.30 \$/gal
= \$8,350 per year

Installed equipment cost = \$9,550.

In addition to the fuel cost savings of \$8,350 per year, resulting from cleaner tubes, a substantial savings in the labour required to hand clean the tubes on a periodic basis (the 400 hp unit has 273 tubes and the 500 hp unit has 293 tubes) was realized.

Cost of improvement: \$9,550.

Recommendation: Look into automatic systems to keep boiler tubes clean and working efficiently. A fast check on the efficiency of the boiler can be made by installing a thermometer in the stack gas as close as possible to the last set of tubes. If the temperature of the gas exceeds the steam/water temperature by more than 100°F, fuel savings can be realized.

Boiler blowdown reduction through feedwater control

The situation: At Inco Limited's Stobie Mine complex the energy conservation committee was concerned that, to maintain desired dissolved and suspended solids concentration in the boiler water of the heating plant, 8 percent of the average output (including chemical treatment) was being blown out of the boiler. The boiler blowdown water contained considerable heat and thus represented a significant loss of energy. Studies indicated that with steady, automatic feedwater treatment control that this blowdown could be reduced by about 50 percent.

Existing feedwater chemical treatment consisted of batch-feeding of corrosion and scaling control chemicals to the three boilers producing a total of 150,000 lbs. per day of steam.

Action taken: A multi-functional liquid boiler treatment coupled with automatic controlled feeding equipment was installed at low cost.

Energy savings: With boiler blowdown reduced to about 4 percent, annual energy savings amount to 2,900 MMBtu's.

Dollar savings: 2,900 MMBtu's/year @ \$2.00 /MMBtu's = \$5,800./yr.

Cost of improvement: \$850.

Recommendation: Before planning steps to utilize boiler blowdown water, take any available steps to minimize blowdown. More effective treatment of boiler feedwater is one definite means to this end.

Boiler metering leads to consolidation, elimination

The situation: Over a period of 20 years at the main manufacturing facility of Griffith Laboratories in Scarborough, Ontario, five separate gas-fired boilers had been installed in various parts of the plant. Originally, provincial regulations had required that these package boilers be operated entirely independently of each other unless maintained by a stationary engineer. Gas consumption of the boilers had never been examined. Given higher energy costs and more recent regulations allowing the combination of similar boilers in a common header (with certain horsepower limits) without need for a stationary engineer, the firm decided to study its boiler efficiency.

Action taken: An individual gas meter was installed on each boiler and the following observations made: one older boiler was operating at 92% of capacity; three others were operating at 40% capacity or less; the fifth boiler was being kept active on a standby basis necessitating routine warmups, service and inspection.

Two steps were taken as a result:

1. The company found that internal costing procedures were not taking gas consumption of the older boiler into account—and the product served by this boiler was actually losing money. The manufacturing process was phased out, the product produced in a different way and the cost of a new boiler avoided.
2. Since studies showed only two boilers were needed. Two boilers were dismantled, sold, and the two remaining were hooked up with a common header with one operating at 90% of capacity and the other one standby for peak requirements.

Energy/dollar savings: Reduced gas consumption from operation of fewer boilers, estimated at $35,000. Additional savings are expected from maintenance, cooling and make-up water requirements, electrical requirements and heat recovery from flue gases.

Cost of improvement: $86,000.

Recommendation: Do not take operating efficiencies of boilers or other combustion equipment for granted. Substantial savings are available in this area. In the case of Griffith Laboratories, more than enough money was saved in one year from the phasing out of the old boiler and switch to a new manufacturing process to pay for the $1,000. per boiler cost of installing five individual gas meters.

Compressed air leak program saves energy

The situation: At the Hamilton, Ontario plant of International Harvester, leaks in compressed air lines were generally only repaired when they caused delays in production.

Action taken: The company instituted a regular program to repair all leaks and continue to repair leaks as they occur. Air leaks totalling 1069 cfm (see chart below) were repaired during the initial crackdown.

Energy savings:

Hole Size	No. of Holes		Loss/Hole		Air Losses
1/64	2	×	.244	=	.488 cfm
1/32	150	×	.973	=	145.950 cfm
1/16	93	×	3.900	=	362.700 cfm
1/8	14	×	15.570	=	217.980 cfm
1/4	1	×	62.300	=	62.300 cfm
3/8	2	×	140.100	=	280.200 cfm
1/2	0	×	249.240	=	0 cfm
3/4	0	×	560.871	=	0 cfm
Total (All Leaks)					1069.618 cfm

Energy loss

$$1069.618\,\text{cfm} \times \frac{500\,\text{HP}}{2800\,\text{cfm}} \times .746\,\frac{\text{Kw}}{\text{HP}} \times 3{,}413\,\frac{\text{BTU}}{\text{Kwh}} \times 8760\,\frac{\text{Hr}}{\text{Year}}$$

$= 4.260$ MMBtu/year

Dollar savings:

Energy cost

$$1069.618\,\text{cfm}\ \frac{500\,\text{HP}}{2800\,\text{cfm}} \times .746\,\frac{\text{Kw}}{\text{HP}} \times 12\,\frac{\text{mos.}}{\text{Year}} \times \frac{\$3.60}{\text{Kw (demand)}}$$

$$+\ \frac{500\,\text{HP}}{2800\,\text{cfm}} \times .746\,\frac{\text{Kw}}{\text{HP}} \times 8760\,\frac{\text{Hrs.}}{\text{Year}} \times \frac{\$.0105}{\text{Kwh (cons'n)}}$$

$= \$19{,}274.52$/year

Cost of improvement:

Repair costs

245.6 Man-hours × $9.51/Man-hour + $350.34 Material = $2,686.00

Recommendation: Carry out a regular, compressed-air and/or steam leak repair program—it can be one of the best investments a company can make to conserve energy.

Compressed air maintenance eliminates compressor

The situation: At the Thorold, Ontario mill of the Ontario Paper Company, management were aware of a major energy saving and cost cutting opportunity in reducing leaks from the 95 psig compressed air system. The mill system consisted of three 1,400 cfm units powered by 300-hp motors and one 2,000 cfm machine with a 450-hp motor. Leaks were known to exist in the intercooler, on one compressor and in piping around the plant; however, given ambient noise levels, it was difficult to pinpoint and repair anything but the largest and most obvious leaks.

Action taken: Mill engineers took advantage of a period when the mill was "down" to implement a major programme of air leak tracing and repair. All leaks were located and marked during the down period and some repair work carried out. The remaining leaks were repaired as part of a longer term maintenance programme following start-up. The leaking intercooler was found to account for 30 percent of the air loss and was replaced.

Energy/dollar savings: After the programme, the company found it was able to eliminate the use of one of the 300-hp compressors—representing a saving of approximately $25,000/year in electrical energy.

Cost of improvement: Not available.

Recommendation: If necessary, look to a similar down period to put in motion an air leak repair

programme. After repairs have been made, it may be possible to eliminate compressors completely, as in the case of Ontario Paper, or possibly to cut the maximum output of a compressor. Both will result in substantial dollar savings for a small investment. (Ontario Paper calculated that a further reduction of 7.5% in horsepower used or $6,000/year could be achieved were it possible to lower main line air pressure to 80 psig.

Compressor cooling water used for boiler make-up

The situation: Management at 3M Canada Limited's London, Ontario plant some years ago saw the benefits in energy and water savings of a system which would collect compressor cooling water and use it, supplemented where necessary by city water, as boiler feedwater.

Action taken: Approximately 2.5 MM gal/yr of compressor cooling water is collected in a surge tank from the intercollers and aftercoolers of the plant's compressors. From here it is pumped into the boiler make-up system ahead of sodium zeolite softeners. During summer months, compressor cooling water volume is more than adeuate for boiler make-up and enters the system at 100-110°F. During the winter, when higher steam demand leads to higher make-up demand, compressor cooling water must be supplemented by city water. In addition, winter-time city water temperatures are about 30°F cooler than summer temperatures — decreasing the volume of cooling water available for recovery.

Energy saved: Over the course of the year, the system saves the equivalent of 8,000 gal/yr of Bunker "C" and about 2.5 MM gal/yr of water.

Dollar savings:
Energy: 8,000 gal/yr @ $.35 gal = $2,800/yr
Water: 2.5 MM gal/yr = 400,000 cf @ $.003/cf = $1,200/yr
Total = $4,000/year.

Cost of improvement: Using surplus equipment readily available in the plant, total cost of the installation was less than $500.

Recommendation: Look to cooling water from compressors, spot welders and other equipment as suitable pre-heated feedwater for boilers, wash/rinse cycles and other applications. Systems are usually simple and inexpensive to install and operate and yield an attractive return on investment based on both the waste heat recovered and the raw water conserved.

Contact pyrometer to detect faulty steam traps

The situation: Dominion Foundries and Steel Limited (DOFASCO) of Hamilton found that one of the most difficult facets of steam trap maintenance is the ability to locate traps which are faulty. Particular problems were encountered when many traps were piped to a common condensate tank.

Action taken: DOFASCO investigated the use of stethoscopes and an infrared camera to detect leaks, but found that the most reliable tool is the contact pyrometer. This is used to measure the surface temperature of the trap discharge piping. Depending on the type of trap and the steam conditions, DOFASCO has been able to develop a link between this exit temperature and the amount of leakage. This technique is now used in its trap maintenance programme.

Energy savings: Potential energy savings of about 10,000 lbs/hr of steam.

10,000 lbs/hr X 1300 Btu/lb X 8760 hrs/yr ÷ 0.8 (boiler efficiency) = 142,350 MMBtu/yr of fuel.

Dollar savings: 142,350 MMBtu/yr X $2.00/MMBtu = $284,700/yr. It is estimated that the cost of finding and repairing leaking steam traps could approach $20,000-$25,000, however the potential benefits are sufficient.
Net dollar savings = $260,000/yr.

Recommendation: Implement a comprehensive steam trap maintenance programme. Trap and steam conditions vary in each case, and extensive testing is required to determine the relationships between the exit temperatures and amount of leakage.

Direct steam injection can save energy

The situation: A plant has a demand for 30 gpm of water heated by steam from 60°F to 160°F for 4,000 hrs/yr. The traditional method using a heating coil and steam trap would involve a considerable loss in energy through the steam condensate return line. By the time condensate returned to the boiler it would have cooled to 120°F.

Action taken: The company utilized direct steam injection for heating the water, saving 14.5 Btu for each lb. of hot water produced (assuming 75% boiler efficiency).

Energy savings: 30 gpm X 8.34 lbs/gal X 60 mins/hr X 4,000 hrs/yr X 14.5 Btu/lb = 870 MMBtu/year.

Dollar savings: 870 MMBtu/yr = 870 Mcf/yr @ \$2.00/Mcf = \$1,740/year.

Cost of improvement: Not available; however, direct cost could be lower than for a comparable system involving steam coil and trap.

Recommendations: Consider the use of direct steam injection to heat water and aqueous solutions—you can save energy as well as installation and maintenance of heat exchangers, traps, and condensate returns. It should be borne in mind that if steam injection is used to heat an aqueous solution, allowance must be made for the diluting effect of the condensed steam. Extensive use of steam requires treatment and additional make-up water—a cost which should be factored into detailed calculations.

Factory compressed air replaced by pressure blower

The situation: At a General Motors plant, compressed air at 100 psig was used in the drying section of a detergent washing operation, used to remove moulding release fluid from instrument panels. As an inefficient use of factory air, it resulted in excessive energy consumption.

Action taken: A 30 horsepower pressure blower was installed to dry the parts. Compressed air service to the drying cycle was cut off.

Energy savings: Previous consumption: 1500 cfm × 9.5 Btu/cf³ × 60 min/hr × 12 hr/day × 235 days/yr = 2411 MMBtu/yr.
Present consumption: 36 amps × 480 volts × $\sqrt{3}$ × .8 × 12 × 3413 = 230 MMBtu/year.
Savings = 2411 − 230 = 2181 MMBtu/year.

Dollar savings:

$$2181\ \text{MMBtu} = \frac{2181\ \text{MMBtu}}{3414} = 639{,}000\ \text{Kwh @ \$.025 Kwh} = \$15{,}975/\text{year.}$$

Cost of improvement: \$5,000 including equipment, ducting and labour.

Recommendation: Look for more economic localized energy alternatives to factory compressed air whenever this is possible.

Feedwater control keeps boiler tubes clean, saves Btu's

The situation: The prevention of scale formation, even on a boiler as small as 500 hp can produce energy savings of \$30,000 per year or more—depending on the thickness and chemical composition of the scale.

Action taken: For a 500 hp boiler in use at its 100% rating of 16.74 MBtu/hr into steam, or approximately 16,700 lb. steam/hr. At its rated 75% efficiency, and operating 8,000 hrs/yr:

Annual energy input
= 16.74 MMBtu/hr × 8000 hr/yr × 1/0.75
= 178,560 MMBtu.

Example A: if scale 1/32" thick is allowed to form on the tubes, and the tubes, and the scale is of "normal" composition (salts of Ca and Mg), reference to chart indicates an energy loss of 2%. Under these conditions,

Annual energy loss
= 178,560 MMBtu × 0.02.
= 3,570 MMBtu per year.
If the scale is cleaned out and prevented from reforming, and assuming the fuel oil used has a heating value of 144,000 Btu/US gal and costs 35¢ per gal., there will be a

Dollar saving
= 3,570 MMBtu × 1/0.144 MMBtu/gal × \$0.35/gal.
= \$8,680 per year.

Example B: If scale the same thickness forms, but of a composition high in iron and silica, a graph indicates an energy loss of 7%.

Annual energy loss
= 178,560 MMBtu × 0.07.
= 12,500 MMBtu per year.
Removing the scale and preventing its reforming with the same assumptions as to fuel oil:

Dollar saving
= 12,500 MMBtu × 1/0.144 MMBtu/gal × $0.35/gal.
= $30,400 per year.

Recommendation: Check boiler tubes visually for scale while the boiler is shut down for maintenance. Operating symptoms which may be due to scale include reduced steam output, excessive fuel use, and increased stack temperature.

If scale is present, consider modifying the feedwater treatment and/or the schedule of chemical additives. The cost of modification can vary widely, depending on such factors as the type of treatment facilities already available and the chemical problems present if any.

Heat transfer fluids used in tracing systems

The situation: An organic chemical plant became aware that substantial amounts of energy were needlessly being consumed by its 32,000 linear foot steam tracing system for process piping. The tracing system used plant steam capable of maintaining the heated product at 365°F while only 248°F was required.

Action taken: The company converted the steam tracing system to an ethylene glycol heat transfer system incorporating a shell and tube heat exchanger.

Energy savings: An average of 23.3 lb/hr of steam was consumed per 100 ft of line when using steam tracing. As little as 8 lb/hr depending on process conditions, was required to heat the fluid to 248°F in the heat transfer system.

Energy savings: Potential savings = (23.3 — 8.0) lb/100 ft/hr × 8,760 hr/yr × 32,000 ft = 42.9 MMlb/yr steam.
This amounts to a potential energy savings of about 43 billion Btu/yr although actual saving attained is approximately 30 billion Btu/yr because of losses due to process and ambient condition variation.

Dollar savings: 30,000 MMBtu = 30,000 Mcf @ $2.00/Mcf = $60,000/yr.

Cost of improvement: Not available; however, the cost of the shell and tube heat exchanger for heating the fluid is stated to be approximately equal to that of steam traps, check valves, thermostatic air vents, drains and fittings in a conventional steam tracing system.

Recommendation: Consider the possibility of converting steam tracing to another type of heating system. Potential savings are greatest when the required temperature in the process line is considerably less than that conveniently maintained by steam tracers. As a rule, the lower the process temperature, the greater the potential saving.

Major steam trap maintenance program exceeds conservation targets

The situation: Traditionally, management at the Maitland Works of Dupont of Canada in Sarnia were not particularly concerned about steam traps. They had always replaced those traps which seemed to be leaking and had run a few "blitz" programs in the fall of the year, but generally these usually yielded to "more important" maintenance activities.

The Works has a central Power House with six boilers and a steam generating capacity of 815 M pph. Steam at 250 and 450 psig is distributed to the various operating areas spread over approximately 100 acres. Average steam load through the year is 600 M lb/hr. A nominal steam cost of $1.90 per 1,000 pounds is used in any loss or savings estimates which follow.

However, in launching its Energy Conservation activities Dupont selected steam trap maintenance as a program which could get off to a fast start and yield results — providing initial momentum, while technical schemes to conserve energy were approved and implemented. In addition, expanded production indicated that the company would be hard pressed to meet production area steam demands in the next winter with the result that energy programs involving steam savings were most likely to receive the necessary resource support.

Following discussion with steam trap manufacturers, it was concluded that a conservative estimate of losses from steam trap failures was 15-30 M lbs/hr (2½-5% of average steam load) with an annual value of $250M-$500M. From these preliminary studies, it was also recognized that the probability of annual trap losses being greater than $1 MM was higher than that of their being less than $200 M. There appeared to be ample assurance that we could recover the estimated labour and material costs of $80 M to evaluate the program for one year.

From preliminary studies, it was concluded that an effective steam trap maintenance program appeared to have the potential of becoming the backbone of Dupont's energy conservation activities.

Action taken: Manpower was assigned on a full-time basis and those involved trained to become specialists in an on-going, year-round activity. Two mechanics were assigned full time, as well as an engineer to provide technical guidance on day-to-day activities and to develop solutions to major problems. A chemical operator was later added to the program when it was apparent the activity was paying off.

To focus on one area, recognizing that experiments and tests would be necessary to develop identification and data recording systems, the scope of the program was limited initially to one operating area, which involves 60-70% of the traps on the plant site.

An effective data recording system was considered essential. The company chose to follow the history of trap locations, rather than individual traps, as they suspected this approach would highlight the locations which presented especially difficult trapping problems. Goals were established for the program which were somewhat more optimistic than the "conservative" estimate of losses.

Short Term: — First year saving of $350 M — equivalent to 21 M pph steam average through the year.

—Reduction in steam load of 42M pph by year end.

Long Term: — Generate the knowledge to achieve improved trap performance with less maintenance through:

—better traps

—correct sizing

—proper selection of trap for the job

—Develop improved trap selection and installation standards for new construction.

Procedures were as follows:

—Tagging each trap location with a numbered stainless steel band wired to inlet piping.

—Recording information including:

—type and size of trap installed

—installation arrangement — vertical or horizontal, open or closed discharge, existence of strainers and isolating valves.

—Testing traps:

—used stethoscope (96% disc traps); planned to evaluate an ultrasonic detector.

—a pyrometer was used as backup for specific types of traps.

—pressure profiles were plotted in condensate systems where there is evidence that back pressure was causing trap failure.

—Criteria for defective disc trap:

—Passing steam continuously; "machine gunning" — cycle time <4 secs. on ½" disc trap or <3 secs on ⅜" disc trap. This standard was considered tentative and will likely change when we generate the information necessary to base it on an ecomomic analysis.

—Defective traps were replaced where they could be isolated without affecting the process and maintain a record of trap replacement for revising the master records and for estimating steam savings.

—Correct obvious oversizing:

—½" disc traps or tracers were automatically replaced with smaller sizes when they failed; suspected oversizing of process traps were referred to the engineer for follow-up.

—Correct trap misapplication:

—Where the wrong type of trap had been used for a specific application, the trap was changed or the condition referred to the engineer.

—A report was issued and recommendations for follow-up by area maintenance crews made where significant piping alterations are involved and where major process shutdown or steam outage is required.

—In addition, an experimental program, a test program, was set up to evaluate a variety of traps in different applications. In time the results of this program will be used in developing standards.

—Traps were evaluated on a test apparatus to

determine performance characteristics and steam losses under varying pressure conditions.

Energy savings:
—Average steam saving first year—20.5M pph net vs Target 21M pph
—Steam load reduction at year end—50.4 M pph net vs Target 42M pph
—Reduction in prime fuel for steam generation due to steam trap maintenance, approximately 35,000 bbl oil.

Recommendation: Implement a steam trap maintenance program, but do not look for immediate results. In the first few months, the cumulative savings may not exceed the precision of the metering instruments. However, as long as defective traps are being replaced with good ones, you can be confident that you are saving steam. In Dupont's current program:
—has expanded trap maintenance to the entire site—now have three mechanics and one operator working full time to service 5,000 traps.
—Has completed three cycles in the area where the program was started and trap defect level is down from 33% to 7%.
—Average steam load is down 105 M lbs/hr (17.5%), compared with the corresponding period before the program, while production volume is down 0.2%. The saving is not all attributed to the steam trap program, as many othe activities are going on to reduce our energy consumption, but trap maintenance has certainly been a significant contributor. Cumulative value of the steam saving to date this year is $1.6MM.
—The company is beginning the process of removing many disc traps on the basis of information generated by the field testing program. The long term goal is to have a trap in each location that gives optimum equipment performance with minimum loss and maximum service life.

Then Dupont program has established that at least 70% steam losses from defective traps can be recovered through an ongoing maintenance program. Aside from the economic benefits, increased equipment capacity, prevention of equipment damage and improved equipment operation and process control could probably justify a steam trap maintenance program on their own.

Outdoor steam condensate tank insulated

The situation: A large steam condensate receiver tank (8 ft. diameter × 14 ft. in length—452 sq. ft. area) at the Leamington plant of H. J. Heinz Limited was not insulated and was losing substantial amounts of heat to the atmosphere. Given the inability to economically move the tank inside and an average yearly thermal differential (condensate temperature less outdoor temperature) of 140°F, the company felt that some form of insulation was necessary.

Action taken: Fibreglass insulation was added to the tank by a contractor.

Energy savings: Average differential heat loss for the insulation is based on:

2.1 Btu/sq. ft/hour/1°F temperature difference.
Savings: $2.1 \times 452 \times 140 = 132{,}888$ Btu/hr.
$= \dfrac{132{,}888 \times 24 \times 365}{1000} = 1{,}164{,}030$ cf/yr.

Dollar savings: 1,164,030 cf/yr = 1,164 Mcf/yr @ $2.00 Mcf = $2,328/year.

Cost of improvement: $2,600 yielding a dcf rate of return of more than 50 percent.

Recommendation: Estimates of heat loss range down to 1 Btu/sq. ft./°F, but if internal space requirements or other factors preclude moving heated process, condensate or other tanks (which require heating to prevent freezing) indoors, carefully consider insulation. At the same time, make sure that condensate return lines are properly insulated. Heinz has also insulated two steam condensate tanks located inside the plant. While dollar savings here were not quite as dramatic, the installation was ecnomically justifiable on the strength of energy savings.

Paint system heat recovery uses steam flash tank

The situation: John Deere Limited, Welland works several years ago seized on an opportunity to improve the energy efficiency of its paint sytem by fully exploiting steam usage potential.

Action taken: A flash tank was installed to capture low pressure (100 psig) flash steam from the hot condensate from high pressure steam traps. All condensate from the steam coils in the washer, dryer and bake ovens are released to the flash tank at 2 psig with 13 percent of the condensate flashing into steam. This flash steam is absorbed in the washer tank at 160°F — providing heat and high temperature makeup for the washing stage. A float regulated valve drains part of the condensate from the flash tank into the washer tank as high temperature make-up water — the balance is pumped back to the boiler. Installation was done during normal working hours with no interruption to the paint system, except the final piping connections which were done on a weekend.

Energy savings: Approximately 14,000 MMBtu/yr.

Dollar savings: Approximately $28,000/yr.

Cost of improvement: $4,500 (in 1967) with a cash payback of less than one year.

Recommendation: Investigate the use of flash steam from condensate collected in steam traps. These systems frequently pay for themselves in reduced energy bills in less than one year.

Reduction in steam pressure follows energy audit

The situation: A steam energy audit was carried out at the Kitchener, Ontario plant of B. F. Goodrich Limited in which plant requirements were compared with boiler house output. The energy co-ordinator at the plant made the steam survey listing all important elements about the steam system — size of line, insulation status, pressures, position of steam traps, location and position of regulating stations, etc. Steam consumptions were measured or calculated.

Action taken: The survey of the steam system indicated that though no production equipment required more than 150 psig, boilers were producing 225 psig steam. As a result, an attempt was made to reduce boiler pressure to 150 psig in gradual steps (200 psig, 180 psig, etc.). At each step, feedback from production departments was solicited and no problems surfaced. At the 170 psig step, engineers found it difficult to control the boiler turbines due to lower pressure and a higher firing rate. The company now maintains steam pressure at a constant 180 psig and enjoys a good evaporation rate.

Energy savings: Due to the inability of segregating the effect of a number of energy conservation projects carried out at the same time, exact values are not known. However, given reduced boiler output, a higher steaming rate, reduced line heat losses and reduced pressure losses through leaks, malfunctioning traps, etc., energy savings are estimated at 5,770 MMBtu/year.

Dollar savings: MMBtu/year = 5,570 Mcf/yr @ 2.00 Mcf = $11,140/year.

Cost of improvement: Time of plant personnel.

Recommendation: Examine the plant steam system with an eye to reducing pressures if possible; finding and fixing leaks and faulty traps — and revising the steam piping system to reduce unnecessary loops. Follow up with a similar investigation of the compresed air system.

Softened compressor cooling water as boiler make-up

The situation: Manufacturers recommendations to use softened water as the cooling medium in rotary screw compressors prompted the management of Libby, McNeill & Libby of Canada Limited to study a system whereby the softened compressor cooling water and its available heat could be recovered and used to advantage. Inlet temperature of water to the compressor had a mean temperature of approximately 45°F and a heat content of 13.06 Btu/lb. After compressor cooling, the 499.8 gph of water reached 195°F with a heat potential of 149.91 Btu/lb.

Action taken: The company installed piping and other necessary equipment to use the nearly 500 gpm of compressor cooling water as partial boiler feedwater make-up.

Energy savings: Heat available = 499.8 gal × 8.3 lbs/gal = 4150 lbs @ 150 Btu/lb. = 622,500 Btu/hr.
However, since the recovered cooling water was to be further utilized to cool condensate returns

from processing equipment, it was decided not to insulate the transmission line from the compressor to the main condensate vacuum pump. The net loss from this line amounts to 22,620/hr leaving a net gain of: 622,500 − 22,620 = 599,880 Btu/hr. Over a period of one year (8,000 hrs. operation): Heat conserved = 599,880 × 8,000 = 4.8 × 10^9 MMBtu/hr. Water conserved = 499.8 × 8,000 = 3,998,400 gals/year.

Dollar savings: Heat: 4.8 MMMBtu = 4,800 Mcf @ $2.00/Mcf = $9,600/year.
Water: $3,233/year.
Total: $12,833/year.

Cost of improvement: $800.

Recommendation: Do not overlook compressor cooling water (and particularly *softened* cooling water) as a source of boilder feedwater. These recovery systems generally offer extremely high Dcf returns on investment and very attractive payback periods.

Steam generation uses incinerator flue gas

The situation: A manufacturer of asphalt roofing had been disposing of 16,000 cfm of asphalt saturated air by burning the mixture in an incinerator at 1400°F. Incinerator exhaust was being discharged to the atmosphere while the company purchased 15,000 lb/hr of process steam at 150 psig from a neighbouring steam plant.

Action taken: Acting on the results of a brief study which showed that flue gases could be used to generate all the steam, and more, needed by the roofing plant, management installed a waste heat boiler in the incinerator stack — capitalizing at the same time on 200°F feedwater available elsewhere within the plant.

Energy savings: To produce one lb of 150 psig steam (366°F) from one lb of 200°F water requires 1026 Btu. Heat required to produce 15,000 lb steam = 1036 Btu/lb × 15000 lb/hr = 15.39 MMBtu/hr.
The flue gas flow rate at a gas density of .0763 lb/cf and standard conditions = 16,000 cfm × .0763 lb/cf × 60 min/hr = 73,248 lb/hr.
With a 2 per cent heat loss and Cp = 0.28 Btu/lb °F, the required temperature drop in the flue gas =

$$\frac{15.54 \text{ MBtu/hr}}{0.28 \text{ Btu/lb°F} \times 73{,}248 \text{ lb/hr} \times (1 - 0.02)} = 773°\text{F}.$$

This means that the flue gas need only be cooled to 1400-773 = 627°F to produce the required 15,000 lb/hr of 150 psig steam.

Dollar savings: Operating 3,000 hrs per year = 15,000 lb/hr × $1.00/Mlb × 3000 = $45,000 per/yr.
If flue gases were cooled to, say, 400°F, a total of 19,400 lb/hr of steam could have been generated with a total cost savings of more than $58,200/yr.

Cost of improvement: $37,000. Even at the lower steam output, payback was achieved in less than one year.

Recommendation: Check into plant exhaust streams with temperatures higher than 300°F as potential sources of heat for steam generation. Some thought should also be given to the potential for selling unneeded steam to a neighbouring plant. Note that cooling flue gas below 300°F can frequently bring corrosion problems caused by condensation of stack gas components.

Steam leaks repaired quickly

The situation: In some areas of Dominion Foundries and Steel Limited (DOFASCO) in Hamilton, steam leaks were repaired by shutting down the steam line in the area affected. This often posed scheduling problems, particularly in areas fed by only one steam line.

Action taken: One technique which has helped in the continuing battle against steam leaks is the use of an outside contractor with special equipment to fix steam leaks "live". This cuts down on the scheduling problems and thereby allows us to get leaks repaired more quickly than would be the case otherwise.

Energy savings: DOFASCO estimates that by using the on-line repair service, the yearly savings could approach an additional 1500 lbs/hr of steam.
1500 lbs/hr × 1300 Btu/lb × 8760 hrs/yr ÷ 0.8 (boiler efficiency) = 21,350 MMBtu/yr of fuel.

Dollar savings: 21,350 MMBtu/yr × $2.00/MMBtu = $42,700/yr.
The outside firm fixed 30 leaks during the year. Cost is estimated at $3,000-$5,000 to repair

these leaks using the specialist.
Net dollar savings — about $38,000/yr.

Recommendation: Consider a steam leak specialist. Use of a firm to repair leaks live on a contract basis has proved profitable for DOFASCO. This is a good way of fixing steam leaks — quickly.

Water spray reduces flash steam loss

The situation: At the Huntingdon, P.Q. plant of Cleyn and Tinker Limited, engineering staff realized that a significant amount of energy was being given up to the atmosphere through the loss of flash steam through a vent serving the 5-10 psi condensate return tank for the company's 125 psi steam system.

Action taken: Based on advice from another company, a simple spray system was set up in which 80 gph of demineralized water from treatment facilities (using just city water pressure) was sprayed into the tank through an atomizing nozzles at 50°F. The system reduced the loss of steam and latent heat through the vent to atmosphere to almost nil. At the same time, it provides 80 gpm of treated boiler feedwater preheated to 212°F (the temperature of condensate in the tank).

Energy savings: No detailed calculations have been carried out, but from basics: Heat recovered = 80 gph = 800 lb/hr × 60 min/hr × 24 hr/day × 6 day/wk × 50 wk/yr × (212 — 50)F° = .933 MMBtu/year.

Dollar savings: .933 MMBtu/yr = 5,060 gals/yr Bunker "C" @ .35/gal. = $1,771.17/year.
Water savings and savings in preheating amount to another $357.09/yr.
Total savings = $2,118.26/yr.

Recommendations: Look to demineralized spray systems to reduce flash steam losses—assuming the flash steam cannot be used for some other purpose more profitably. Cleyn and Tinker stress the importance of both a fine mist from the atomizer and an extremely fine screen to remove any suspended solids before water reaches the atomizing nozzle. Flash steam not only contains latent heat, it should be seen as pretreated feedwater. The cooling water would be required as feedwater anyway, but would have needed to be heated from city water temperature in the boiler.

Weekend compressed air reduction saves energy

The situation: At a General Motors plant, 100 psi air pressure service was maintained to all parts of the factory for 24 hours a day, all year round regardless of requirements.

Action taken: Plant air pressure was reduced to 40 psi—the lowest level allowable given the requirement for continual operation of paint pumps to stir metallic paint mixtures—on weekends and for periods of extended downtime.

Energy savings: Previous consumption: 1500 cfm × 9.5 Btu/cf^3 × 60 min/hr × 24 hrs/day × 365 days/yr. = 70,000 MMBtu/year.
Present consumption: = 56,000 MMBtu/year.
Saving: 70,000 — 56,000 = 14,000 MMBtu/year.

Dollar savings: 14,000 MMBtu/year = 4.1 MM Kwh/yr @ .025 Kwh = $100,000/year.

Cost of improvement: Nil.

Recommendation: Cut steam and compressed air pressure to the lowest possible levels during periods when the plant is "down". No investment is required to produce real energy savings.

Tips for saving money through steam and compressed air management

1. Fully insulate all steam and condensate lines, process equipment.
2. Cover, insulate condensate tanks.
3. Repair or replace faulty steam traps.
4. Repair all other sources of steam leakage including flanges and high pressure reducing stations.
5. Maintain steam jets used for vacuum system.
6. Assure boilers are operating at peak efficiency.
7. Keep boiler tube surfaces clean.
8. Return condensate to boiler — or use pre-softened cooling water from compressors, etc. as feedwater — to minimize both blowdown and overall energy and water consumption.
9. Monitor boiler blowdown chemical analysis.
10. Recapture blowdown energy using heat exchangers or flash tanks.
11. Use air heaters and / or economizers to recover heat from boiler flue gases.
12. Minimize the distance steam must travel by re-arranging process equipment, eliminating straggling steam laterals.
13. Use isolation valves to split up the steam distribution system.
14. Operate steam-heated processes at the lowest permissible temperature.
15. Lower steam pressures wherever possible.
16. Use steam traps and / or balanced pressure air vents to eliminate air films in steam lines.
17. Put flash steam to work in lower pressure applications.
18. Where clean condensate cannot be returned to the boiler, use it for washing or other processes.
19. Turn off steam tracing during mild weather.
20. Look to glycol tracing systems to replace steam.
21. Consider replacing electric motors with back pressure steam turbines and use exhaust steam for process heat.
22. Operate distillation columns at minimum quality requirements.
23. Operate distillation columns at near flooding conditions for maximum separation efficiency.
24. Determine correct feed plate location on distillation columns to increase efficiency and minimize steam consumption.
25. Consider switching selected steam stripping distillation units from direct (live) steam to indirect (dry) stripping.
26. Use correct size steam traps.
27. Evaluate replacing condensing steam turbine rotating equipment drives with electric motors, if your plant has a power generating capability.
28. Add traps to distillation column to reduce the reflux ratio.
29. Minimize boiler blowdown with better feedwater treatment.
30. Use waste heat low pressure steam for absorption refrigeration.
31. Replace barometric condensers with surface condensers.
32. Shut off steam traps on superheated steam lines when not in use.
33. Optimize operation of multi-stage vacuum steam jets.
34. Use optimum thickness insulation.
35. use reflux ratio control or similar control instead of flow control on distillation towers.
36. Substitute hot process fluids for steam.

Compressed air.

1. Make optimized selection of central compressor versus a number of smaller zone compressors.
2. Choose the compressor with the highest ratio of cfm delivered to brake horsepower.

3. Select an air intake location that provides dry, clean air.
4. Maintain compressor driving belts, and all other critical parts.
5. Ensure that water cooling ducts are not blocked.
6. Use larger or extra receivers on existing compressors.
7. Investigate automatic control systems.
8. Provide basic instrumentation to guage system efficiency.
9. Repair all line leaks promptly as part of a regular maintenance program.
10. Use long radius bend and welded joints wherever possible in piping.
11. Incorporate strainers and lubricators in each air-operated device.
12. Regularly maintain air operated equipment as well as "conditioning units" — filters, pressure regulators, and lubricators.
13. Do not operate equipment above manufacturer's recommended operating pressure.
14. Reduce air pressure to lowest feasible level.
15. Consider double acting air cylinders.
16. Use hot air from remote receiver tanks close to cylical loads.
17. Use hot air from air cooled compressors for space heating wherever economically vialble.
18. Cooling water from water cooled compressors has many potential uses within the plant.

Steam table (imperial units)

Gauge Pressure (psig)	Saturation or Boiling Temperature (Degrees F)	Specific Volume (Cu. Ft./Lb.)	Heat Content Above 32 Degrees F		
			Sensible Heat or Heat of Liquid (Btu/lb.)	Latent Heat or Heat of Evaporation (Btu/lb.)	Total Heat (Btu/lb.)
0	212.0	26.80	180.1	970.3	1150.4
1	215.5	25.13	183.6	968.1	1151.7
2	218.7	23.72	186.8	966.0	1152.8
3	221.7	22.47	189.8	964.1	1153.9
4	224.5	21.35	192.7	962.3	1155.0
5	227.3	20.34	195.5	960.5	1156.1
6	229.9	19.42	198.2	958.8	1157.0
7	232.4	18.58	200.7	957.2	1157.9
8	234.9	17.81	203.2	955.6	1158.8
9	237.2	17.11	205.6	954.1	1159.7
10	239.5	16.46	207.9	952.5	1160.4
11	241.7	15.86	210.1	951.1	1161.2
12	243.8	15.31	212.2	949.7	1161.9
13	245.9	14.79	214.3	948.3	1162.6
14	247.9	14.31	216.4	946.9	1163.2
15	249.8	13.86	218.3	945.6	1163.9
16	251.7	13.43	220.3	944.3	1164.6
17	253.6	13.03	222.2	943.0	1165.2
18	255.4	12.66	224.0	941.8	1165.8
19	257.1	12.31	225.7	940.6	1166.3
20	258.8	11.98	227.5	939.5	1167.0
21	260.5	11.67	229.2	938.3	1167.5
22	262.2	11.37	230.9	937.2	1168.1
23	263.8	11.08	232.5	936.1	1168.6
24	265.4	10.82	234.1	935.0	1169.1
25	266.9	10.56	235.6	934.0	1169.6
30	274.1	9.45	243.0	928.9	1171.9
35	280.7	8.56	249.8	924.2	1174.0
40	286.8	7.82	256.0	919.8	1175.8
45	292.4	7.20	261.8	915.7	1177.5
50	297.7	6.68	267.2	911.8	1179.0
55	302.7	6.23	272.4	908.1	1180.5
60	307.3	5.83	277.2	904.6	1181.8
65	311.8	5.49	281.8	901.3	1183.1
70	316.4	5.18	286.2	898.0	1184.2
75	320.1	4.91	290.4	894.8	1185.2
80	323.9	4.66	294.4	891.9	1186.3
85	327.6	4.44	298.2	899.0	1187.2
90	331.2	4.24	301.9	886.1	1188.0
95	334.6	4.06	305.5	883.3	1188.8
100	337.9	3.89	308.9	880.7	1189.6
105	341.1	3.74	312.3	878.1	1190.4
110	344.2	3.59	315.5	875.5	1191.0
115	347.2	3.46	318.7	873.0	1191.7
120	350.1	3.34	321.7	870.7	1192.4
125	352.9	3.23	324.7	868.3	1193.0
130	355.6	3.12	327.6	865.9	1193.5
135	358.3	3.02	330.4	863.7	1194.1
140	360.9	2.93	333.1	861.5	1194.6
145	363.4	2.84	335.8	859.3	1195.1
150	365.9	2.76	338.4	857.2	1195.6
155	368.3	2.68	340.9	855.0	1195.9
160	370.6	2.61	343.4	853.0	1196.4
165	372.9	2.54	345.9	850.9	1196.8
170	375.2	2.47	348.3	848.9	1197.2
175	377.4	2.41	350.7	846.9	1197.6
180	379.5	2.35	353.0	845.0	1198.0
185	381.6	2.30	355.2	843.1	1198.3
190	383.7	2.24	357.4	841.2	1198.6
195	385.8	2.19	359.6	839.2	1198.8
200	387.8	2.13	361.9	837.4	1199.3
210	391.7	2.04	366.0	833.8	1199.9
220	395.5	1.95	370.1	830.3	1200.4
230	399.1	1.88	374.1	826.8	1200.9
240	402.7	1.81	377.8	823.4	1201.3
250	406.1	1.74	381.6	820.1	1201.7
260	409.4	1.68	385.2	816.9	1202.1
270	412.6	1.62	388.7	813.7	1202.4
280	415.7	1.56	392.1	810.5	1202.7
290	418.8	1.52	395.5	807.5	1202.9
300	421.8	1.47	398.7	804.5	1203.2
400	448.2	1.12	428.1	776.4	1204.6
500	470.0	0.90	452.9	751.3	1204.3
600	488.8	0.75	474.6	728.3	1202.9

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	$N \cdot m$	J
Power	watt	J/s	W
Electric charge	coulomb	$A \cdot s$	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	$V \cdot s$	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	$cd \cdot sr$	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	$N \cdot m$
Viscosity-dynamic	pascal second	$Pa \cdot s$
Thermal conductivity	watt per metre kelvin	$W/(m \cdot K)$
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	$J/(mol \cdot K)$

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	1° = (π/180) rad
minute (of arc)	′	1′ = (π/10 800) rad
second (of arc)	″	1″ = (π/648 000) rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY IN TRANSPORTATION AND DELIVERY

7

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Office of Energy Conservation
Bureau de la conservation de l'énergie

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SAVING MONEY IN TRANSPORTATION AND DELIVERY 7

Saving money through Transportation and Delivery

Introduction:

Transportation of materials and people consumes a large percentage of the fossil fuels used in Canada every year. As such a major energy consumer, it is naturally a major target area for industrial energy conservation programs.

This booklet attemps to cover a number of in-plant and ex-plant subject areas which are relevant to the industrial company intent on reducing its energy bills in the transportation sector. Particular emphasis is given to operation and maintenance of company car and truck fleets.

Transportation . . . a top priority

As the costs of both diesel fuel and gasoline climb over the dollar per gallon figure, saving energy in transportation and delivery is becoming a top priority.

The price of fuel is now more than double what it was in 1971. Fuel costs account for about 7½ per cent of the total operating costs in any trucking operation — not a huge figure, but a significant one because fuel consumption can be controlled more easily than many of the components of trucking costs. These costs have a direct relation to company profits, and if lowered, can reduce the impact of inevitable further increases in the price of fuel.

The most visible energy conservation measure is the air deflector, and more and more of these devices mounted on cabs to streamline vehicles are appearing. However, the largest single saving can be achieved by substituting diesels for gasoline engines. Other methods include better driving habits and use of fan clutches and radial tires.

And savings in transportation and delivery are not limited to trucking. Improvements also can be made to company car fleets, and in-plant measures such as lift truck maintenance and air locks on loading dock doors can be very effective energy conservers.

Transportation accounts for one quarter of Canada's energy usage. This figure includes all modes including private cars, buses and trains, but use of cars and trucks for transportation and delivery in the industrial sector constitutes a large portion of this consumption. As a result, the potential volume of savings is significant and should be actively pursued.

A look around the plant is all it takes to identify potential savings in relation to lift trucks and loading docks. And an examination of car and truck fleets will find still other ways to save energy. Both areas offer a real opportunity to make mileage with energy conservation.

In-plant operations

Of the transportation-related measures which can be carried out in Canadian plants, among the most significant are those related to increasing lift truck fuel economy.

Lift truck operations

Hidden from sight, the motors in an electric lift truck are generally assumed to be protected from hazards like extensive exposure to abrasives, moisture and accidental blows. Yet, they are subject to their own brand of abuse through operating conditions and techniques and maintenance practices.

Most owners pay attention to battery maintenance, the hydraulic systems and the masts. But practical tips on using and maintaining a DC traction motor and a pump motor in an electric vehicle are in order. Naturally, lift truck pump drive and propulsion motors will deliver better fuel economy if they are well looked after. Some of the tips for better maintenance are detailed on the following page.

Off-peak charging of lift truck batteries is another way to save on energy bills. Often, battery chargers are started at the beginning of the first work shift, a practice which incurs an additional electrical load during a peak demand period, resulting in extra demand charges from the electrical utility. By charging batteries during

Tips on Lift Truck Maintenance

Item	Do This	Don't Do This
Brushes	Inspect periodically and replace brushes before damage to commutator possible.	Allow to wear to condition where shunts or rivets rub on commutator.
	Replace brushes that have loose shunts.	Use brushes with loose shunts either tamped or riveted.
	Replace brushes with defective shunts or that have loose terminal connectors. Always inspect and tighten brush terminal connections to cross connectors.	Use brushes with oxidized shunts due to excessive heating or defective shunts or shunt terminal connectors.
	Replace with new brush grade as recommended by brush and/or the motor manufacturer.	Replace same brush grade that exhibits rapid brush wear resulting in heavy carbon deposit on motor interior.
	Always use brush grade as recommended by the manufacturer or use a grade that has proven field performance. Replace all brushes at the same time.	Never mix brush grades on motor during brush replacement.
Terminals	Inspect, clean and tighten all terminal connections during every routine inspection.	Don't allow external or internal cable connections to become loose — Results in burnt terminals due to excessive heating and eventually causes motor failure.
Commutator	Remove motor and check for cause. Commutator should be turned, cleaned and undercut. Mica slivers must be removed.	Allow commutator to become pitted, grooved, out of round, rough surfaced or discolored.
	Inspect and repair commutator or install new armature.	Allow operation with high or low commutator bar or bars.
Brush Springs	Check spring pressure during routine inspection, replace if necesary.	Don't operate motor with bent, discolored, badly corroded or discolored springs. Could result in improper brush pressure and cause poor commutation, excessive brush wear due to mechanical vibration or electrical wear.
Fans	Check fan during routine inspection and replace if necessary.	Permit motor operation with fan loose or broken blades. Fan loose on shaft could cause damage to field coil insulation or excessive noise or vibration. Broken blade or blades could result in insufficient air flow, excessive motor heating.
Motor Shaft Seal	Check for evidence of Transaxle lubricant in motor interior during routine inspection. If present, check seal and replace.	Permit motor operation with defective drive end shaft seal. Its purpose is to prevent transaxle lubricant from entering motor. Could cause insulation failure, poor commutation resulting in excessive sparking and rapid brush wear.
Motor Interior	During routine inspection remove and clean thoroughly. When cleaning use only solvents recommended for electrical equipment. Do not use cleaners containing silicones or chlorines.	Allow motor interior to become dirty from excessive carbon dust, lubricant, hydraulic fluid, dirt or other atmospheric contaminates. Could result in motor failure, or excessive heating — poor commutation, insulation failure.
		General: truck cleaning. Don't clean trucks with liquids or solvents containing silicones. Rapid brush wear could result.
Covers	Check — repair or replace during routine inspection.	Allow bent, broken or missing covers. Bent or damaged ventilating covers restrict air passage through motor and cause ground faults. Insufficient air could result in excessive heating — motor failure. Missing covers: purpose of covers it to protect motor from foreign objects — screws, nails, stones, dripping battery acid, etc. from getting into motor. Missing covers offer no protection to motor interior and could cause severe electrical or mechanical damage.
Motor	Check truck maintenance manual for frequency and methods for proper maintenance. Keep accurate and continual records to assure maximum motor reliability.	Don't rely on habit or memory for routine motor maintenance schedules.

the second shift, when peak demand is much lower, money can be saved on electrical bills. One General Motors plant saved almost $10,000 in one year (see case history). The same principle can be used for other energy consuming activities which need not be carried out during peak demand periods. Peak load schedulers or "load shedders" should be investigated to make further use of this concept.

Kimberly-Clark, for example, has found in tests that propane powered fork lift trucks, equipped with catalytic mufflers and capacitor discharge electronic ignition systems require less maintenance, less downtime, less fuel and give better reliability than standard propane-powered units. But for these results to be achieved, the trucks should be tuned with diagnostic ignition analyzers and carbon monoxide gas analyzers. Among the conclusions of the tests was that it is possible to reduce fuel consumption up to 20% and to reduce maintenance material and labor costs using the diagnostic equipment on a regular maintenance program. Early results indicate that 15-20% savings in material and labor costs were possible.

In addition to energy savings, the tests showed that heating and ventilation costs in all of the firm's Canadian plants could be reduced, and that greater protection from fork truck exhaust emissions could be given to plant personnel.

Air Locks for Loading Doors

A substantial loss of energy occurs every time a loading door is opened to the outside during loading and unloading operations with no means of preventing heat escape from the building interior. This energy loss may be reduced by installing an air lock at the loading door.

A structure or device which prevents the unloading door from being directly exposed to the outside when open, air locks require quite a substantial capital expenditure — $20,000 for a door 20 ft. x 17.5 ft. And for any specific installation the savings obtained would vary widely depending on prevailing winds, length and severity of the heating season, the size of the opening, and the cost of energy for space heating (see case history for calculation of savings). In general, air locks should be considered for loading doors which are open frequently or for extended periods of time.

There are other ways to save energy in loading dock areas. Fixed walls, fireproof canvas or plastic curtains and other barriers can be used to limit access of cold air from loading and receiving docks to the plant or warehouse floor (see case history). Dock shelters can be installed on loading docks. They come in a variety of designs and can, under some conditions, pay for themselves in a single season (see case history).

Use of such barriers often means that heating equipment can be eliminated. General Motors disconnected five gas-fired door heaters when it installed a metal wall with two doors and weather curtains at the edge of its receiving dock. GM saved over $17,000 per year and the cost of improvement was only $2,100 (see case history).

Savings in use of cars

Many companies encourage their employees to buy small cars, ride to work in vanpools or carpools, or use staggered hours to save fuel. But the company can achieve even more energy savings when it is responsible for buying the cars used by its salesmen and other employees.

Du Pont of Canada, for example, expects to save $30,000 per year in energy at today's prices by converting all the cars in its fleet from large to intermediate-sized cars. As of October, 1976, there were 220 cars in the fleet and by December, 1976, 44% were intermediate-sized. The expected savings are about $160/car/year at the current price of gasoline, and this figure does not take into account the lower maintenance charges for smaller cars.

There are many things a company can do to save energy in its car fleet — but purchasing smaller cars with smaller engines and cutting down on such gas-guzzling features as air conditioning are prime.

URBAN FUEL ECONOMY TABLE*

Curb Weight (Lbs.)	Approximate Fuel Economy (Miles per gallon)	6000 Mile Fuel Cost (@ 85¢ per gallon)
1950	30	$170
2450	25.5	200
3200	20.5	249
3700	18.5	276
4200	16.5	309
4700	15.5	329

*Based on data submitted to Transport Canada by auto manufacturers as part of the emission control program.

The company can also encourage energy savings by making better use of its cars. Often, company vehicles are returned to a garage or lot at the end of the day to remain idle until the next morning. This capital equipment can be more effectively used by allowing employees to drive the vehicles home at night if they form carpools. Such a program is already operating at the Arkansas State Highway Department in Little Rock, Arkansas. Here, state vehicles carrying a minimum of three carpool riders are permitted to be taken home at night. (See also book #8.)

Saving energy in trucking

The majority of changes to save energy in industrial transportation and delivery involve trucks. And without any expenditure, routing and load optimization are prime considerations — that is, to consolidate routes so that trucks are utilized as fully as possible, and so that fewer trips are needed. Getting more payload into fewer trips reduces the number of times the weight and frontal area of a truck are transported, and therefore cuts the amount of fuel needed to move each ton of freight. The table shows the results of operating at various gross weights in order to move 6,300 tons of freight over a 200-mile route.

GCW (lb)	50,000	55,000	60,000	65,000	70,000
Payload (lb)	25,000	30,000	35,000	40,000	45,000
Number of trips needed	504	420	360	315	280
Fuel Used					
Miles/gallon	4.64	4.55	4.45	4.36	4.28
Gallon/trip	43.20	44.00	44.80	46.00	46.80
Total gallons	21,773	18,480	16,128	14,490	13,104
Gallons/ton of freight	3.46	2.93	2.56	2.30	2.08

*Based on information from Mainstem, Inc.

For internal trucking operations, routing control is strictly an internal consideration and should encounter few barriers. CGE, for instance, has done much work to assure that trucks operating between Toronto and Montreal are fully loaded for backhaul whenever possible. "Deadheading" wastes fuel.

For common carriers, however, routing control involves taking a look at where the customers are, and deciding whether certain routes can be combined; and, in some cases, whether people can do with deliveries less frequently.

For such a program to work to its fullest extent, customers must be informed of the reasons for the change, and negotiations must be made with customer management. Less frequent service often promotes better utilization. But, given the competitive nature of business, it is impossible to give a customer slower transit times than he demands. Consultation and a reasoned approach in many cases will establish that a somewhat lower standard of service will be acceptable in non-critical areas if the reasons are clearly explained.

Among the important tips for routing are the following:

- Consider consolidating routes. Avoid unnecessary trips. Eliminate overlaps.
- Attempt to discourage or eliminate special deliveries of orders.
- Work with retail outlets to eliminate special delivery deadlines.
- Consider cutting delivery frequency where possible.
- Consider structuring routing on a seasonal basis.
- Ensure optimum vehicle load.
- Combine routes for vendor and sign maintenance and similar services.
- Consider consolidation of sales, complaint service calls, and cooler delivery for most efficient truck usage.
- Consider using radio-controlled vehicles to change routing while on road.
- Examine warehouse locations to improve delivery efficiencies.
- Increase route volume per truck where possible.
- Schedule delivery times to avoid rush-hour traffic where possible.
- Work with local officials regarding restricted parking which affects delivery efficiency.

Driver Training

One of the biggest variables in conservation of energy in trucking is driver performance. If drivers make a habit of "jack-rabbit" starts or leave engines idling for long periods of time, many of the savings gained through other measures will disappear.

And one of the worst problems is long periods of idling. Particularly for gasoline engines idling results in considerable fuel wastage. Raw fuel may wash lubricating oil off cylinder walls and dilute crankcase oil so that all the moving parts of the engine will suffer from poor lubrication. So it's clear — when not using the engine, drivers should be instructed to shut it down.

Strange as it may seem, idling does not even make a contribution to keeping an engine warm in cold weather. In fact, one engine manufacturer has proved that if the engine is shut down in cold weather, it will remain warmer after one hour in the shut down position, than it would running at 800 or 1,000 rpm — with the added advantages of major fuel savings, no noise and no air pollution. Use of auxiliary starting equipment, discussed later is vastly preferable to leaving the engine idling.

Some other tips for drivers include:

- Staying 200 rpms under the governor maximum to save fuel.
- Not hitting the governor with every shift. It takes extra fuel to go to maximum rpm with every shift.
- Keeping a light foot on the accelerator and brake pedals to conserve fuel — not hotrodding or sliding to a stop.
- Gearing down when necessary, rather than lugging. Lugging the engine takes extra fuel, and it increases the likelihood of early overhauls and breakdowns on the road.
- Checking tire pressure. Keep your tire pressure up, since it's easier on the tires and saves fuel.
- Preventing spillage. Make sure extra fuel isn't spilled when you refuel. Don't top the tank! Keep your fuel cap tightened so that you don't lose fuel through evaporation or spillage.
- Staying alert and rested. Drive safely and conserve fuel. A tired driver is erratic, doesn't shift gears when he should, and fails to hold his speed. Driving this way uses extra fuel.
- Keeping the engine tuned. An efficient powerplant burns less fuel.

One further tip — stick to lower speeds. The speed limit has been lowered to 55 mph in some provinces already, but even where the speed limit is higher, slowing down makes sense. The table shows the kinds of fuel savings that can be made in a trucking operation using a 65,000 lb GCW, 13.5 van tractor / semi-trailer combination.

Engine Type	Geared Speed at 21000 rpm (mph)	Cruise Speed Limit (mph)	Engine Speed at Cruise (rpm)	Average Speed (mph)	Fuel Economy (mph)
A	59	No limit	2100	54.9	4.51
		55	1950	50.9	4.86
		50	1780	47.1	5.10
C	64	No limit	2100	59.5	4.26
		60	1970	56.9	4.60
		55	1800	52.0	4.93
B	70	No limit	2100	64.7	3.85
		65	1950	60.4	4.35
		60	1800	56.9	4.60

Reducing speed from 65 to 55 miles per hour will cut air resistance by 25% and will also reduce rolling resistance by 14%. This could result in a fuel saving of more than 15 percent.

There are three major approaches to making drivers slow down, each with its own advantages and drawbacks:

- using a road speed governor
- using a tachograph to enforce a fleet speed limit
- motivating the driver to want to maintain lower speeds.

Motivating the drivers, is generally the most successful approach. Share truck mileage and fuel consumption data with drivers to encourage savings efforts.

Remember, driving slower is helpful only as long as the driver can make effective use of top gear. Below about 1800 rpm, the driver will drop back a gear and cruise at high rpm again.

The Right Truck for the Job

One way to ensure efficient and economic operation is to make sure the truck is specified correctly. Often the engine is too small, resulting in failure through overwork since it is operating at better than 80% of capacity for half the time and 100% for the remainder.

Another common mistake is retiring power units purchased for highway operation to city use.

Such trucks are not powered or geared correctly and can't be expected to perform properly.

Unsuitable specifications affect overall operating costs, including fuel consumption. Make sure you have chosen the right truck for the job.

Preventive Maintenance

Good preventive maintenance is one of the fundamentals of fuel economy. Make available and encourage mechanics to use the shop manual when tuning a truck. A well-thumbed manual can be a good indication of superior vehicle performance.

Adherence to a regularly scheduled program of preventive maintenance is the best way to prevent major breakdowns. The costs of the effort are minor in relation to the benefits. It doesn't require a professional mechanic to do some of the simple jobs such as changing oil and filters, but neglect in these areas can severely shorten the life of your fleet. Sixty-days, in fact, is a good interval between tune ups. Post a check-board in a visible place detailing what work is supposed to be done on what vehicles and when. The results in better fuel economy are sure to justify the time expended.

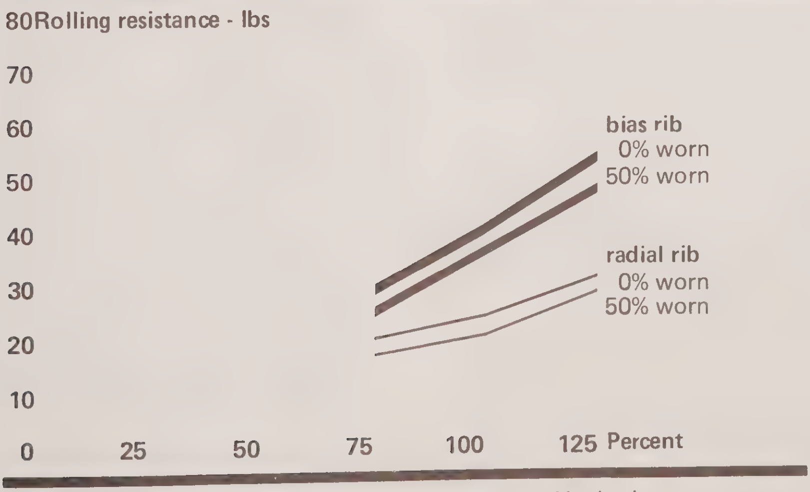
Radial Tires for Energy Conservation

Radial tires offer great potential for energy conservation in terms of fuel consumption, tire wear, improved retreadability and reduced downtime. Radial plies eliminate shear stresses and lower rolling resistance resulting in lower power consumption, lower operating temperatures and lower spring rates. The difference is due to the purely radial direction of the body ply cords which perform the load carrying function as opposed to the diagonal crisscross pattern of the conventional bias ply tire. The addition of belts to the carcase or body gives added stability to the tread and improved puncture protection.

Other advantages of radial tires:

- Longer wear, resulting from the more rigid construction which produces significantly less tread movement on the pavement. Tread life is 48 percent longer than the standard rib tire, and 10 percent longer than cross bar.
- Cooler running, resulting from reduced hysteresis loss and lower power consumption.
- Better impact penetration, resulting from the improved construction. Reduced cutting and puncturing reduces downtime 50-75 percent and improves the percentage of carcases available for retreading.
- Equal or better traction due to reduced tread deflection.
- In most cases handling is improved, although some drivers dislike handling characteristics on gravel roads.
- Reduced shoulder tearing.

Rolling Resistance of Bias Rib and Radial Tires



Percent of maximum loading per Tire & Rim Association Yearbook.

Fuel Savings with Radial Tires: Fleet Experience

Fleet	Type of Operation	Fuel Savings
A	Long Haul, General Freight	6% fuel savings with tractor, 10% with tractor and trailer
B	Long Haul, General Freight	5-9% fuel savings with tractor and trailer
C	Long Haul, General Freight	4% savings with tractor
D	Long Haul, General Freight	Increase of .2 mpg or 4.4% (assuming 4.5 mpg)
E	Long Haul, General Freight	8.6% fuel savings
F	Long Haul, Specialized	4-5% fuel savings with tractor
G	Long Haul, General Freight	Increase of .2 mpg or 4.4% with tractor (assuming 4.5 mpg)
H	Long Haul, Bulk	Increase of .5 mpg or 11.1% with tractor (assuming 4.5 mpg)
I	Long Haul, General Freight	Combined increase of .3-.4 mpg or 6.7-8.9% (assuming 4.5 mpg) with both radials and fan clutches.
J	(Private), Food Store Delivery	Little fuel savings
K	(Private), Food Store Delivery	Gain additional 20 hp, derate engine accordingly to save fuel

Source: Communications with fleet operators.

Many tests of the differences in fuel consumption caused by use of radial tires, has found an average 6% improvement in fuel consumption compared with the bias ply tire. In certain applications such as buses, this improvement reached 12%.

The one major disadvantage to the use of radial ply truck tires is cost. But while the initial outlay can be nearly 25% higher, the increased initial and retread mileage resulted in a 37% increase in the value per truck due to radials. This is in addition to the 6% improvement in fuel consumption.

Gasoline or Diesel — Which is Best for You?

Diesel engines offer many advantages in terms of energy conservation, and as fuel prices rise, they are becoming more and more popular. Vastly superior fuel economy, longer life, less maintenance and less downtime are among the benefits diesels offer. But offsetting these advantages to some extent are the higher costs of diesels — the price differential can be $4,000 to $10,000 more than gasoline-powered trucks.

The fuel savings gained by using diesel engines can be quite impressive — as much as 50% under stop-and go urban driving conditions and 20% on the road. These savings are even more notable when one considers that the price of diesel fuel is often lower than gasoline, and that diesel fuel has 14,000 Btu more energy per gallon than gasoline.

Another significant advantage of the diesel engine is the money it saves in terms of

maintenance and availability. It is hard to place a dollar value on equipment breakdown, but in some operations, loss of income can amount to more than the value of the equipment causing the delay, making even a minor breakdown expensive.

One of the reasons for fewer breakdowns is that components of a diesel engine are normally built of heavier material, are more metallurgically perfect and are designed to withstand more abuse than the gasoline engine. Another reason is that in nine out of ten cases, a gasoline engine road failure will either be caused by a malfunction in the electrical ignition system or because the engine has overheated. Diesel eliminates the first problem because it does not require external ignition systems. The diesel is not troubled with overheating because diesel exhaust temperatures are not nearly as high as those of gasoline engines and because the diesel does not have to burn extra fuel to cope with the vacuum effect caused by the carburetor in gasoline engines.

Preventive maintenance costs about half that of the gasoline-engined vehicle. There are longer intervals between oil and filter changes and overhauls since engine life is similar to chassis life in relatively low mileage applications. And there is less unscheduled downtime.

An example of just how economical a diesel engine can be, occurred at Smith Transport in North Bay, Ontario. Driver René Ouellette and mechanic John Sheridan ran 100,000 miles at an operating cost of 3.4 cents per mile (excluding fuel and tires) with a 1973 tractor with a mid-range diesel engine. The truck was on a steady run, doing between 115 and 200 miles a day with little city driving.

There are some disadvantages to the diesel engine, besides the higher initial cost. Diesel engines have had a reputation for being dirty in the past, but problems with emissions have largely been overcome. Caterpillar Tractor Company has made studies showing that diesel truck engines with precombustion chambers emit the lowest level of contaminants of all truck engines; and that regular diesel truck engines are relatively clean — certainly well below the stringent U.S. government regulations.

One disadvantage that must be faced is the need for auxiliary starting aids (larger batteries, gasoline-fired hot boxes, ether or glow plugs, or electric block heaters) in cold weather operation — a factor to be considered in our Canadian climate.

One of the major criteria when deciding whether to use diesels is mileage — if your trucks travel extensively you can probably justify the cost of diesel engines. Other factors include load weights and speeds — but in any case, diesels are an energy-saving option well worth investigating.

Aerodynamic Drag Reduction Devices

Aerodynamic drag reduction devices, such as wind deflectors are intended to lessen that part of the engine's total power requirement devoted to overcoming wind resistance. And while there is often some question of manufacturers' claims for potential fuel savings, virtually everyone agrees that aerodynamic drag accounts for a major portion of a truck's horsepower requirement when it is moving at highway speeds.

Air resistance is caused by the pressure drag created by the movement of a flat surface perpendicular to an air stream. The airstream hitting a moving rig is deflected to the sides and over the top of the vehicle. And in tractor/van-trailer combinations, one of the major causes of air resistance is the sharp change in the shape of the vehicle at the point where the trailer begins. The airstream is deflected over the top of the cab, but hits the front of the trailer and falls into the gap, creating turbulent air motion. This turbulence in the gap increases the air resistance and therefore the power requirement and fuel consumption of the engine. Another more turbulent area is at the rear of the trailer created in the wake of the moving vehicle.

There are several types of devices available for aerodynamic drag reduction. These include: 1) wind deflectors mounted on cab tops to deflect air flow over the top of the van or trailer; 2) vanes which turn the airflow around trailer corners; 3) rounded trailer corners and fairings mounted on the forward flat face of the trailer; and 4) gap fillers to reduce turbulence in the gap between tractor and trailer.

The table on the following page shows some of the devices on the market today, and the manufacturers' claims regarding performance.

Summary of Claimed Results of Aerodynamic Drag Reduction Devices

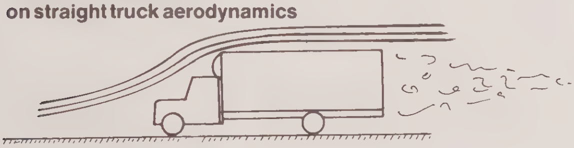
Company Trade Name	Type	Installation	Available	Estimated Cost	Drag Reduction Claim	Fuel Reduction Claim	Basis for Claims
Airflo	Deflector	Cab Top	Yes	$230-260[a]	11.14%	18-30% 10-33%	Road Test, NASA Road Test, Bendix Track Field Tests by Users
Airshield	Deflector	Cab Top	Yes	$215	16-24% 11% 7.6-17%	6.7%	Road Test, NASA Wind Tunnel Test, Purdue Road Test Aerovironment
GMC "Drag-foiler" [a]	Deflector	Cab Top	Yes	$400	up to 35%	9%	Wind Tunnel Test, General Motors Corporation
Windbreaker	Deflector	Cab Top	Yes	$140	N/R	7-11.9%	Field Tests by Users
Uniroyal Air Deflector	Deflector	Cab Top	Yes	$235-310[a]	20%	10%	Road Test by Manufacturer
S^3 Air Vanes	Turning Vanes	Trailer Front Edges	Yes	N/R	6-25% 2-3%	4.2-8.6%	Wind Tunnel Test, GALCIT Road Test, S^3 Road Test, NASA
Blair-Lefler	Turning Vanes	Cab Top	No	N/R	11%	3-7%	Road and Wind Tunnel Test, Wichita State University
Vehicular Stator	Turning Vanes	Cab Top (Pickup Only)	Yes	$275	N/R	12-27%	Road Test, University of Oklahoma
Trailer Duct	Air Duct	Trailer Top	No	N/R	47%	N/R	Wild Tunnel Test, University of Utah
Aeroboost	Rounded Corners Top lip only Complete Set (top & 2 side lips)	Trailer Front	Yes	 $124 $295	 10% 34.6%	 4% 17.3%	Road Test, Aerovironment, Inc.
Nose Cone	Rounded Fairing	Trailer Front	Yes	$265-295[a]	11%	 6-11% 7-37%	Road Test, NASA Road Test, Aerovironment Field Tests by Users
Payne Inc.	Edge Fairing (Retractable)	Trailer Vertical Corners (Front)	No	N/R	N/R 50%		U.S. Marine Corps R&D Program for Amphibious Vehicles. 2-D Water Table Test
Aerovane	Gap Filler (Retractable)	Cab Mounted (Tractor/Trailer Only)	No	N/R	 19%	 6-7%	Wind Tunnel, Vanderbilt University Road Test, NASA Road Test, Georgia Tech
Vortex Stabilizer (Used with Airshield)	Gap Filler	Trailer Front	Yes	$90		3.62%	Road Test, Molded Materials Company
Vehicle Space Closing Means	Gap Filler (Inflatable)	Inflatable Device; Attached on Rear of Cab	N/R	N/R	N/R	13%	Road Test by Developer

N/R = Not Reported
[a]Updated by communication with company representative or from information in company brochures.
Source: Innucept, Inc., *An Evaluation of Truck Aerodynamic Drag Reduction Devices and Tests,* for the National Science Foundation, June 1975.

Other recent tests in the National Research Council's Low Speed Aerodynamics Laboratory confirm that all eight of the truck and trailer add-on devices tested reduce wind drag to some extent; and that all of them would pay for themselves in fuel savings inside of a year. The tests also revealed that there is no wind drag reduction device that outperforms the others in every set of circumstances; that direction and wind velocity, weight, configuration and travel speed of the payload carrier all play a major role in the performance.

Interestingly enough, parallel road tests conducted for the Department of Energy, Mines and Resources and Transport Canada showed that use of air deflectors on straight trucks resulted in a significantly higher percentage fuel savings — 9-14% as opposed to the 4-5 percent achievable on tractor trailer combinations. It is worth stressing that manufacturers' claims of attainable fuel economy are often exaggerated. The chart on page 10 shows experience with air deflectors on semi-trailers in the U.S.

Effect of air deflector on straight truck aerodynamics



The fuel economy improvement is in the neighbourhood of 0 to 5%, and the cost of these devices ranges from $200 to $350. As the NRC tests show, there are no hard and fast rules as to which aerodynamic drag reduction devices are the best — that depends on the type of truck and its use.

Use of Double Trailers on Trucks

As payload weight increases, fuel economy on a productivity basis also increases, since as the gross vehicle weight increases, the rate of increase in fuel consumption per mile is less than the rate of increase in weight. Load space can be increased by using longer or multiple trailer combinations within the appropriate length limit. A typical single 40 ft. semi-trailer has a volume of 2,700 cubic feet; two 27 ft. trailers have a combined volume of 3,600 cubic feet; three 27 ft. trailers have a combined volume of 5,400 cubic feet; and two 40 ft. trailers have a volume of 5,400 cubic feet. Doubles, therefore, provide one-third more cube than singles, while triple and double 40s provide 100% more capacity than singles.

The potential savings to be realized by the use of doubles and triples versus singles for both high and low density freight are shown in the table on the following page. These data were derived from computer simulations of typical tractor/trailer travel over selected western U.S. routes. Two observations are apparent: that triples provide much greater fuel savings than doubles; and that savings are greater in the case of low density freight than for high density cargo. Obviously, provincial length and weight regulations may limit the applicability of doubles and triples as an energy conservation measure.

Projected fuel savings have also been made on the basis of road tests performed by a motor carrier. The results show a 21% fuel consumption advantage using triples instead of doubles and a 15% fuel savings realized by using double 40 foot trailers as opposed to a single, 40 foot semi-trailer. The latter result corresponds to operations involving high density cargo in which the maximum weight limit is reached by the combination.

Automatic versus standard transmissions

Almost all fleet operators engaged in line-haul activity seem to reject automatic transmissions. They feel that no fuel savings are realized through their use and the benefit of reduced shifting is less striking when compared to a six-speed manual transmission coupled to a high-torque engine. The higher cost of the automatics — $3,800 for a road tractor compared to the manual six-or ten-speed cost of about $800 — is a factor discouraging their use. Some companies have tried automatic transmissions, but none have adopted their use for the fleet as a whole.

However, there is some acceptance for automatic transmissions in local pick-up and delivery operations where the shifting of gears is considerable. Evidence from refuse haulers, short-haul operators, and furniture haulers indicates average savings of between 6 and 10% can be achieved through use of automatic transmissions.

The manual or semi-automatic manual transmissions have marginally better mechanical efficiencies. However, it takes a very skilled, constantly-fresh driver to take advantage

Wind averaged drag coefficients and estimated fuel usage at 55 mph for data averaged over three tractor-trailer separations (33 in., 53 in., 73 in.).

		(COE tractor)			(Conventional tractor)			(Straight truck)		
	Configuration	White Freightliner WFT8664 GCVW = 70,000 lb.			I.H.C. 1800 Loadstar GCVW = 55,000 lb.			I.H.C. 1600 Straight Truck 20 ft. Box, GVW = 18,000 lb.		
		W.A.C.$_D$	MPG	Fuel Savings Per Year**	W.A.C.	MPG	Fuel Savings Per Year**	W.A.C.$_D$	MPG	Fuel Savings Per Year**
	Baseline	0.98	4.58	—	0.94	5.32	—	0.88	8.62	—
TRAILER MODIFICATIONS	Square corners	1.07	4.36	-1102	1.31*	4.75	-2240	—	—	—
	Refrigeration unit	0.94*	4.69	490	0.91	5.42	354	—	—	—
	Bevelled nose	0.91+	4.77	856	0.93+	5.35	118	—	—	—
	12 in. Radius — front top, side cors.	0.91	4.77	856	0.84*	5.68	1179	—	—	—
	½ cylindrical nose	0.88+	4.85	1225	0.84+	5.68	1179	—	—	—
	Rounded ½ cylindrical nose	0.86+	4.92	1470	0.80+	5.83	1651			
TRACTOR MOUNTED DEVICES	Airglide	0.91	4.77	856	0.92	5.39	236	0.86	8.78	31
	Airshield (old setting)	0.91	4.77	856	0.90	5.46	472	—	—	—
	Airshield (new setting)	0.86*	4.91	1470	—	—	—	—	—	—
	Airshield (old setting + Gap Seal)"	0.86	4.91	1470	0.86	5.60	943	0.73	9.95	232
	Airshield (new setting + Gap Seal)"	0.82*	5.03	1960	—	—	—	—	—	—
	Uniroyal (old pin setting)	0.90	4.80	980	0.92	5.39	236	0.78	9.46	155
	Uniroyal (new pin setting)'	0.86	4.91	1470	0.90	5.46	472	0.75 ‡	9.75	201
	G.M. Dragfoiler #	0.87	4.89	1347	—	—	—	—	—	—
	G.M. Dragfoiler # (+ Gap Seal)"	0.83	5.00	1837	—	—	—	—	—	—
TRAILER MOUNTED DEVICES	Vortex stabilizer (+ airshield, old setting)	0.90	4.80	980	0.88	5.23	708	—	—	—
	Nose Cone	0.87	4.88	1347	0.83	5.71	1297	0.68	10.48	309
	Aeroboost ¢	—	—	—				0.76	9.65	186
	S^3 Airvane (top only)	0.92*	4.74	735	0.87*	5.56	825	0.80	9.28	124
	S^3 Airvane (top + sides)	—	—	—	—	—	—	0.69 ‡	10.37	294

NOTES: WAC_D Wind averaged drag coefficient
** Based on 100,000 mi. for combinations and 15,000 mi. for straight truck (Imperial gallons)
* Data taken at 53 in. separation only
\+ Data taken at 21 in. separation only
\# Modified version constructed for the Freightliner and not the optimum, but close to it.
¢ An approximation using ½ cylindrical cover fairings.
‡ Estimate based on limited data
" Gap Seal is in experimental stage only, not available for sale
' Angle of deflector readjusted as a result of NRC wind tunnel tests

Fuel Savings with Fan Clutches: Fleet Experience

Fleet	Type of Operation	Fuel Savings
A	Long haul, general freight	2.5%
B	(Private) Food store delivery	5.0%
C	Long haul, specialized	1.5-5.8%
D	Long haul, general freight	4.5-5.0%
E	Long haul, general freight	4-6%
F	Long haul, general freight	Increase of .2 mpg or 4.4% (assuming 4.5 mpg)
G	Long haul, general freight	Combined increase of .3-.4 mpg or 6.7-8.9% (assuming 4.5 mpg) with both fan clutch and radial tires.
H	Long haul, bulk	4.3-16.7%

Source: Communications with fleet operators.

of this, and show improvements in trip times and improved fuel economy. In reality, the lower general level of skill and the effects of fatigue during an eight-hour shift often result in less efficient operation such as lugging or overspeeding the engine due to incorrect gear engagement. There are also less tangible effects such as higher rates of wear on transmissions, clutches and drive axles.

The automatic can decrease the need for a skilled driver, maintain a driver's level of efficiency throughout his shift, enable him to concentrate on the road, protect the engine and drive train from abuse and yield better trip times in congested stop-and-go conditions.

Another advantage can be better utilization of automatics. Smith Transport reported that in 1973 it had ten new automatic vehicles for city operation, and thirty manuals. All vehicles otherwise had identical specifications. Recent records indicated an increase of approximately one-third in the automatic vehicles' utilization factor. One operation in Montreal averaged 35,000 miles versus the manual's 22,000. Thus, a reduction in fleet size due to use of automatics may be possible.

Fan Clutches

Cooling fans don't have to operate for the entire time an engine is running to fulfill their function. In fact, most of the time the ram air created by the vehicle's movement is sufficient to cool the engine. Installation of a demand-actuated fan drive system, popularly known as the fan clutch, can save a good deal of energy by ensuring that the fan runs only when needed.

There are three kinds of fan clutches on the market:

The simple air-activated on/off clutch. With this type, the fan is either fully engaged or fully disengaged. Some are engaged by air and disengaged by means of a spring, while others are engaged with a spring and disengaged by air. This type of clutch has the greatest potential for fuel savings since the fan is completely disengaged when cooling is not needed. It is also the simplest and is very easy to repair; however, it can impose severe shock loads on fan belts and bearings when engagement takes place instantaneously, and the sudden power loss and increased noise level can be annoying to the driver.

The viscous drive system. This system results in a variable fan speed that is neither completely engaged nor disengaged. The clutch provides torque for the fan by the shearing action of silicone fluids between the input and output members of the drive system. Viscous drive has the advantage of being completely self-contained with no connections to the vehicle's air supply or cooling system, and it is the least expensive to install. But, since it does not disengage completely, horsepower savings, and therefore fuel savings, are less than those of the on/off clutch. The viscous fan clutch maintains a variable fan speed over a range of 45 to 90% of input speed; however, because the maximum air flow is still less than manufacturer's design, retrofitting may require an adjustment of the drive pulley ratios or installation of a larger diameter fan to protect the engine at times when maximum cooling is required.

The modulated fan clutch. This provides a variable fan speed but also the complete lock-up as in the case of the on/off fan clutch. The sensors here operate on the basis of expansion of melting wax. The wax pellet is sensitive to engine coolant temperature, and as the temperature changes, the valve changes the air pressure which provides variable fan speed. Another modulated fan clutch uses a temperature-sensitive wax pellet to control mechanical pressure to the fan directly. Either system provides the most accurate control of fan operation with variable fan speed provided over the range of complete lock-up to 10 to 20% of input speed. However, this type of clutch is the most complex of the three designs, has a greater chance of failure, and is the most expensive.

Fan clutches do offer great potential for savings, since studies show that the fan is required for less than 10% of the time the engine is running. Of course the savings are not as great for a heavily loaded vehicle engaged in slow speed, stop-and-go driving or climbing steep hills in hot weather — since all these factors affect the need for cooling. But a year-long test involving a large unit and an on/off fan clutch, hauling over mountainous western Canadian routes, showed that fan hours as a percent of total engine hours ranged from 0.13% in January to 8.62% in July. And, with the exception of July and August, the average monthly percentage of fan operation never reached more than 2.1%.

The fuel savings realized by use of fan clutches range from 3 to 10% according to a U.S. Department of Transport/Environmental Protection Agency study, with long-haul carriers expected to realize maximum savings of 7 to 10% and local trucks at the bottom of the scale with savings of 3 to 7%.

Prices for fan clutches range from $100 to $500 and fleet experience has concentrated on retrofitting existing units. However, the cost of the fan clutch specified on a new purchase is about $100 less than the cost incurred by retrofitting.

Fan clutches also reduce the vehicle's noise level. Actually, for many U.S. fleets, the fact that fan clutches enable trucks to meet government noise levels is a major incentive for installation.

A major disincentive is that reliability and durability are sometimes questionable. In some cases, the engineering is beyond the capability of the user. And in some retrofit applications, extensive alterations and adjustments to existing cooling systems must be made in order to install the fan clutch system in place of the constant drive unit. If the user does not possess the necessary knowledge, insufficient cooling and engine failure might result. Another cause of increased downtime might be extreme shock loads on the fan belts and bearings when the clutch instantaneously engages during over-the-road operation.

Despite these purported disadvantages, Smith Transport has used fan clutches successfully, and the company reports that it can get an extra 17 hp from rigs using the on/off fan clutch system. This gain in horsepower allows the fuel supply to the engine to be cut back by a full five percent and still maintain satisfactory highway performance. From this and other case history evidence, fan clutches are well worth investigating.

Automatic radiator shutters are one of the best devices for controlling engine temperature within the fairly narrow recommended range. This is not significant from a fuel economy point of view, but it will save money by adding to engine longevity.

Engine and Drive Train Modifications

It's hard to make any generalizations regarding engine and drive train modifications — such is the wide variety of components on vehicles

today. In addition, each component is interdependent so that changes to one may require adjustments to others in order to maintain adequate performance. And, because of these inter-relationships, it is hard to isolate and ascertain impacts of modifications on fuel economy.

While retrofitting can be very effective in other areas of energy conservation, its applications in this area are limited. Modifications to engines in existing units can achieve fuel savings, but usually at the expense of performance. And though many of the measures may appear inexpensive in themselves, they may require substitutions or alterations to other equipment such as transmissions or drive axles. These alterations are generally quite costly.

New "fuel economy" engines and matching drive train components are available on new vehicles at little or no additional cost above the standard engine options, and these new engines have been improved so that fuel savings are realized together with improved vehicle operation performance.

Possible modifications to engines and drive trains include the following:

Derating engine horsepower. This measure can improve engine longevity, reduce maintenance cost and save fuel in cases where there is an excess in power above that required for the vehicle's operation. Derating the engine involves recalibrating the fuel injectors to deliver less fuel than that stipulated in the original horsepower rating. Power should not be derated to the point where geared cruise speed cannot be maintained since the amount of shifting required will increase. A disadvantage is lower performance capabilities and increased trip times.

Derating is most effective when used in conjunction with radial tires, fan clutches and aerodynamic drag reduction devices — ensuring that power gained from these measures is not misapplied elsewhere. And since power requirement is reduced along with power availability, the difference in performance is not as great.

A computer simulation has shown that for a 70,000 pound tandem tractor with a 12.5 foot high trailer and a geared speed of 61 mph at 2100 rpm, derating horsepower alone from 290 to 255 hp resulted in a 4.8% fuel savings but a 3.7% loss in trip time. However, with the addition of radial tires, fuel savings nearly tripled to 13.7% and travel time lost was only 0.2%.

Road Speed Chart for Selected Combinations of Engine RPM and Rear Axle Ratios

(miles per hour)

Engine RPM (hundreds)	Rear Axle Ratio										
	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7
16	51.3	49.9	48.6	47.4	46.3	45.2	44.1	43.1	42.2	41.2	40.4
17	54.5	53.0	51.7	50.4	49.2	48.0	46.9	45.8	44.8	43.8	42.9
18	57.7	56.2	54.7	53.4	52.1	50.8	49.6	48.5	47.4	46.4	45.4
19	60.9	59.3	57.8	56.3	54.9	53.6	52.4	51.2	50.1	49.0	47.9
20	64.1	62.4	60.8	59.3	57.8	56.4	55.1	53.9	52.7	51.6	50.5
21	67.3	65.5	63.8	62.3	60.7	59.3	57.9	56.6	55.3	54.1	53.0

Note: Road speeds shown for each gear ratio are based upon the transmission in direct gear and the ability of the engine to run at the rpm shown. There is no consideration for engine power, type of terrain, load or air resistance. This chart is based on tire size 10.00-20 tube tires (11.00-22.5 tubeless tires).

Source: Eaton truck speed chart from the Truck Components Group of Eaton Corporation.

U.S. government estimates show fuel savings due to derating of the engine to be about 2 to 5%.

Reduction of engine speed (rpm). Conventional diesel engines generally operate at a maximum of 2100 rpm at which point the governor limits the fuel flow to the engine. However, optimum fuel efficiency occurs around 1600 to 1800 rpm. If the governor is adjusted to reduce maximum engine speed, the driver is forced to operate the vehicle in a more fuel-efficient way. But the resulting reduction in road speed can cause additional shifting, and this means increased driver fatigue and increased wear on the drive train components.

As with derated horsepower, reduced engine speeds will maintain vehicle performance only if other components are appropriately altered. For instance, if the lower performance resulting from rpm reduction enables the vehicle to perform its task without alteration to the drive train, adjusting engine speed provides an economical way to conserve fuel. Benefits include lower noise levels, improved engine durability and reduction of maintenance requirements. Again, savings are maximized when power requirements are reduced by use of radial tires, air deflectors, etc. The chart shows the kind of savings that can be expected, and how savings are maximized by using radial tires.

Reducing the axle ratio. This reduces the engine speed needed to maintain a given road speed, and keeps the engine performing at a more fuel-efficient level. However, it also increases the amount of shifting required and can result in longer trip times. The savings gained by doing this are generally less than those achieved by reducing engine rpm — and range from 0 to 5%. The lower axle ratio must be matched with correct gearing and torque characteristics. Good fuel economy can be obtained if a 5 or 6 speed transmission is used so that the cruise speed can be maintained while in top gear; if a high-torque rise engine is used so that increased shifting does not occur at low speeds; and if the high speed capability of this combination is not abused.

This axle ratio reduction can effectively be used in combination with reduced engine speed so that rpms can be reduced with no change in road speed.

It should also be borne in mind that new engine drive train systems on the market can eliminate many of the problems involved in these modifications by adjusting both engine speeds and drive train components to accommodate high torque-rise engines.

Fuel consumption is lowered by a reduction in maximum governed engine speed and performance is enhanced by the increased torque characteristics of the engine and drive train. Improvements in the fuel system and turbocharger result in higher torque at lower rpm ranges. Coupled to a transmission and rear axle ratio with wide enough gear splits, this high-torque rise engine provides relatively constant horsepower over a wide range of rpms. The effect of this combination is that as engine speed goes down due to grades or winds, the driver feels that he has more power and he can thus refrain from downshifting. The increased torque and "fast" rear axles enable the vehicle to maintain road speed and keep the transmission in top gear.

Self-Steering Axles

It takes a good deal of energy for trucks to negotiate turns, and one of the devices that can make turning easier and therefore save energy, is the self-steering axle. The difference between a self-steering axle and the regular axle system is shown. Energy savings are due to reduced power requirements since tires are not being dragged sideways over the highway surface.

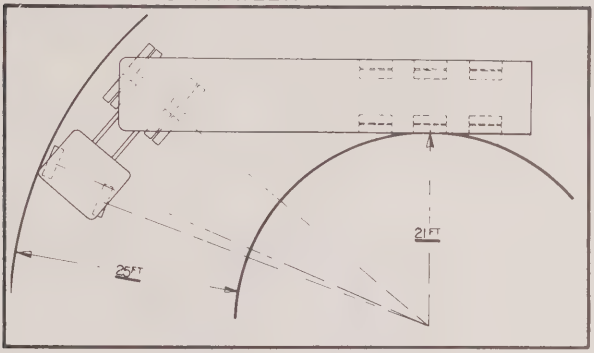
These self-steering trailers have many advantages apart from the obvious benefit of increased tire life. They can also turn more easily than standard trailers and use about 20% less road to turn. Both rear axles are steering and the trailer pivots on the axle ahead. This balanced system means reduced load shifting problems and improved turning time.

Turns are easier on the truck for another reason. In many cases on non self-steering trailers, drivers will lift the third axle in order to negotiate bends a little easier. When they do this, they overload the remaining axles, suspension, main rail and drive train. Some trucks have two or three axles that lift, operated from the tractor via an electrical solenoid.

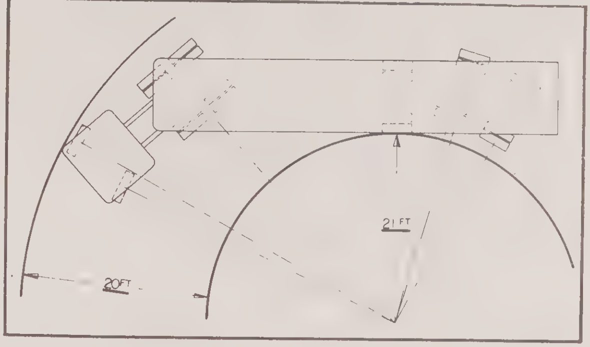
Self-steering trailers also pull more easily than fixed axle trailers. On a flat highway there can be a two to three gear advantage — meaning increased energy savings.

Negotiating turns with Standard and Self-Steering Trailers

45′ STANDARD TRAILER



45′ SELF STEERING TRAILER



Some provinces have legislation pertaining to axles. British Columbia has a law whereby any axle above a spread of 65″ has to steer. Alberta also has legislation regarding steering axles, and Manitoba is conducting tests.

Five self-steering trailer systems are currently manufactured in volume in Canada. Some use a cable system driven by the angulation at the fifth wheel to turn an axle or combinations of axles to steer the appropriate radium required. Others use a castoring action of the wheels with air or hydraulic damping to help eliminate road shock, minimize effects due to wheel eccentricity, and provide a positive steering action. Still another system steers a complete bogie assembly with a central pivot and is driven by the angulation at the fifth wheel.

Fuel Additives

Although there are several fuel additives on the market, claimed savings should be treated with some skepticism because of a lack of controlled test data. It is possible that some additives could result in decreased fuel mileage and even damage to the engine.

Trends in energy conservation

New developments in energy conservation are already changing the nature of transportation and delivery. But how will the industry respond to even greater fuel price increases in the 1980s and 90s?

Aero Mayflower Transit Company has already designed its "Truck for Tomorrow" (see Case History section), complete with many of the fuel saving devices described earlier. But other changes, some of them quite radical, are forecast for the next two decades.

Alternative power sources

One of the biggest questions is whether new power sources will be used. Alternatives such as turbine (Brayton Cycle) and electric vehicles are now being tested, the former in over-the-road bus and truck operation and the latter in local pick-up-and-delivery. However, it is unlikely that such radical changes will be applied in substantial numbers during the 1980s.

Gas turbine engines continuously burn fuel with excess air for low emissions. The fuel/air mixture is expanded through a turbine to provide power. Fully-developed gas turbine engines are expected to offer a fuel economy advantage of almost 30% over a conventional gasoline engine in a full-size passenger car with a cost penalty of between \$20 and \$280 in 1974 dollars.

However, today's gas turbines still show a 20% fuel economy penalty when compared with over-the-road diesel engines in Greyhound buses. They tend to have poor idle and part-load fuel economy and may have trouble with stringent NO_x standards.

Electric powered vehicles are quite, simple, and clean. However, today's battery technology limits them to very short-range pick-up-and-delivery work. Their use may increase if petroleum prices continue to rise and

more energy is generated from coal or nuclear fuel.

Another alternative, the Stirling continuous combustion engine theoretically offers up to 47% fuel economy and could be used in cars as early as the late 1980s. Because of the relatively undeveloped state of the engine, its use in trucks is not projected until well after 1990. The Stirling is similar to a steam engine, except that it uses a gas, which is alternately cooled during compression and heated during expansion.

Changing gasoline engines.

Evolutionary changes in gasoline and diesel engines appear to be very likely for the 1980s. "Lean-burn" gasoline engines with computer controls — which reduce the fuel-to-air mixture ratio in a spark-ignited engine — provide the lowest fuel consumption for a specific driving demand, along with lower emissions. Fuel injection systems may become more widely used in conjunction with the lean burn systems. Fuel injection overcomes the carbureted system's inability to provide a uniform mixture of fuel and air to the individual combustion chambers. Fuel economy improvements of up to 10% may be possible if fuel injection were to be introduced on gasoline truck engines, depending on the efficiency of the existing carburetor.

Turbocharged gasoline engines are another trend. Turbochargers are exhaust gas driven air compressors which increase the cycle efficiency by extracting work from the otherwise discarded exhaust heat, and using it to increase the ability of the engine to deliver power by increasing the quantity of air available for combustion. If used properly, the turbocharger will also provide an increase in fuel economy by allowing a smaller, more efficient engine to replace a larger, naturally aspirated engine. Turbocharging is most effective at high engine speeds when there is sufficient exhaust gas flow to power the turbocharger and allow it to deliver maximum intake air volume. A 10 to 20% fuel economy improvement is thought to be possible.

Stratified charge gasoline engines, designed so that combustion takes place in two stages are now used in some passenger cars, and can effect a 5 to 10% fuel economy improvement over current gasoline engines. A relatively rich fuel/air mixture is ignited in a separate pre-chamber. This initial ignition then spreads to the remainder of the combustion chamber, which houses a very lean mixture, giving the effect of a very lean overall mixture.

Improving the diesel

Another desirable trend appears to be increased dieselization due to the durability, reliability and fuel economy described earlier in the book.

Diesel engines will continue to improve. New families of engines offering high torque-rise and lower governed speed are already available. These engines are all turbocharged. And it appears likely that future engines for over-the-road use will not only be turbocharged, but aftercooled for both emissions and fuel economy improvements. Possible further improvement to the basic diesel engine cycle is suggested in the so-called "bottoming cycle" — where waste heat of the exhaust is used to drive a separate Rankine cycle heat engine. The U.S. Energy Research and Development Agency has estimated a 15% increase in fuel efficiency from the bottoming cycle used to augment driveline power or to drive accessories.

Lubricants

Decreased engine and drive train friction losses can be expected through the widespread use of two improvements in lubrication.

Early problems with Molybdenum Disulfide (MoS_2) as an oil additive have now been solved, and one supplier reports that a 1% MoS_2 suspension may improve fuel economy by 3%, contribute to a reduction in sludge, varnish and wear, reduce oil viscosity increase due to oxidation, and improve cranking speed at -20 degrees Fahrenheit.

Synthetic lubricants — man-made products formed by a chemical synthesis from two or more materials — are another relatively new idea in the trucking field, and seem to have many potential energy conservation implications. They are currently being studied by the Mobility Equipment Research and Development Command of the U.S. Army (MERADCOM).

Potential capabilities include:

- Between 3.5 and 20% (cold weather) fuel savings.
- Extended oil drain intervals.

Possible Economy Measures

Item	Manufacturers' Claim	Users' Report	Independent Testing
	Figures are given as percentage of fuel saved		
Speed Limit Reduction (65 to 55 mph)	—	—	—
Improved Maintenance	—	—	14.5
Improved Driving Methods	—	—	—
Aerodynamic Aids	up to 37	16	up to 10
Fitting of Radiator Shutters	12 to 28	—	—
Variable Speed Fan Drives	4 to 10	—	—
Synthetic Lubricants	up to 31	25 to 32	—
'Doubling-Up' of Trailers	—	up to 50	—
Elimination of Unnecessary Idling	—	—	—
Conversion, Gasoline to Diesel	—	40 to 50	
Retrofit of Turbocharger	4 to 15	—	—
Turbocharger Plus Transmission/Axle Changes	up to 25.5	—	—
Fitting of Radial Ply Tires	1 to 8.5	up to 20	—
Fitting of Wide Single Tires on Drive Axles	—	—	—
Use of Single Powered Axle Instead of Dual	2.5 to 3	—	—
Derate Engine and/or Reduce Engine Speed	up to 10	—	—
Various Bolt-On Economy Devices	up to 15	13 (gasoline)	—
Fitting of Tachograph	10 or more	—	—
Avoid 'Rush-hour' Traffic on Urban Expressways	—	—	—
Rail Piggyback	—	—	—
Better Utilisation of Trailer Capacity	—	—	—
Self-Steering Trailers	up to 17	—	—

- Longer engine life.
- Reduced downtime.
- Labour savings.
- Easier winter starting and faster warmup.
- Easier disposal of used oil.

There are three types of synthetic lubricants which have been seriously considered for motor oil use:

- The polyglycol type, which is suitable, but cannot be mixed with petroleum-based lubricants.
- Synthetic hydrocarbons, which are superior to petroleum-based lubricants in low-temperature behaviour and also have some high-temperature advantages.
- Diesters of Organic Acids and Alcohols. These have capabilities desirable for potential extended-drain motor oils. They have been used in the extreme operating temperature environment of jet engines for 25 years. They have the additional advantage of being bio-degradable.

The cost of synthetic oils is currently about $13 to $14 per gallon compared to about $4 for regular motor oil. But as prices of petroleum products rise, synthetic lubricants will become more and more viable.

Other trends

It's hard to keep track of all the recent innovations in the transportation and delivery field. A miles-per-gallon indicator, developed by a supplier for use on new or retrofitted trucks, is one of the latest inventions. It should cost between $100 and $300 (U.S.).

Many of the trends build on ideas mentioned in this book — and it is clear that the transportation sector is working hard to overcome the problems of higher fuel costs.

A program for your fleet

The list of ways to save energy and money in transportation and delivery seems endless — particularly in trucking operations. Many of these improvements have been incorporated in the new truck designs. But everyone can't afford to buy new trucks. Retrofitting is the alternative, and in many cases, modifications can be very effective in achieving fuel savings. Caution, however, should be exercised when adjusting parts of the engine or drive train, since modifications to one part may mean expensive alterations to other inter-related parts.

Don't just limit your program to modifications. Educate employees to help you in your program — by driving more slowly; by going easy on the engine; by paying more attention to vehicle maintenance; by spotting areas for savings; and by loading vehicles properly.

Transportation is one of the areas in which energy-saving devices are constantly being developed and improved. Keep abreast of new developments which may provide energy savings for your fleet. In conjunction with in-plant measures, they can contribute significant savings to overall corporate objectives.

Canvas curtain cuts loading dock heat loss

The situation: Two large loading doors used for receiving steel coils and for loading scrap material are located in a wall of the Leigh Metal Products plant in London, Ontario. During winter, management realized that large volumes of warm plant air were being lost whenever doors were opened. Complaints were being received from employees working in adjacent areas, but because coils are delivered on flatbed trucks, there was little means of using door bumpers to effect a seal around the door when open.

Action taken: Acting on their own initiative, plant engineers had a fireproof canvas curtain made. The curtain hangs from floor to ceiling and has a transparent plastic window to allow fork lift truck drivers to see through to the other side before passing through the slit in the middle. The curtain appears to retain significant amounts of warm air in the plant area and reduces the direct flow of cold air blowing into the pressroom area.

Energy/dollar savings: No direct measurement. It was felt that some steps had to be taken. Given the low cost and the empirical evidence that heat is being saved, management is satisfied.

Cost of improvement: $2,200.

Recommendation: Look into one of the many feasible solutions for reducing heat loss through open loading dock doors. Several designs of plastic and other curtains for this purpose are commercially available. Check with your fire insurance company to make sure curtain material meets with their approval before purchase.

Diesel delivery trucks offer benefits

The situation: Labatt Brewery's Quebec operations include a fleet of more than 160 delivery vans which until late in 1975 were entirely gasoline powered. The company realized that given higher fuel costs, diesel engines would offer significant energy savings along with lower exhaust pollution, less downtime, longer warranty and a number of other benefits.

Action taken: Gasoline powered trucks in the company's fleet replaced with diesel powered trucks.

Energy savings:
Previous per truck consumption:
9,000 mi. @ 4 mpg = 2,250 gals/yr.
Present per truck consumption:
9,000 mi. @ 8 mpg = 1,125 gals/yr.

Dollar savings:
2,250 gals @ $.89 gal = $2,002
1,125 gals @ $.78 gal = 878
Per truck savings = $1,124/year

Cost of improvement: Additional cost per engine = $3,000.

Recommendation: Look to diesel engines as a source of real dollar savings when replacing existing engines or specifying new on the road equipment. As fuel prices increase, diesel engines will represent an even more attractive energy saving investment.

Among the auxiliary benefits of diesel power are: reduced maintenance costs due to elimination of spark plugs, coil, condenser, carburetor, distributor and wires and reduced overhauls due to greater engine reliability. Assuming a truck life of 8 years and a $500. higher trade-in for diesel over gasoline engines, even allowing for higher initial investment, total dollar savings for Labatt's amount to more than $5,000 per truck.

Fleet of compact cars means fuel savings

The situation: Most of the cars in the fleet used by 3M Canada's salesmen were intermediate-size — consuming more fuel than available compact cars.

Action taken: Starting in November, 1976, 3M Canada started to purchase compact cars as replacements for intermediate-sized cars as these were retired from the fleet. There is still a "mix" of cars, but the breakdown of anticipated savings follows.

Energy savings: Fuel economy (combined highway and city driving) for a compact car = 20.4 mpg; and for an intermediate car = 18.0 mpg. Average yearly mileage and gallon usage for a compact:
= 21,000 miles ÷ 20.4 = 1030 gals (U.S.).
Average yearly mileage and gallon usage for an intermediate-sized car:
= 21,000 miles ÷ 18.0 = 1166 gals (U.S.).

Dollar savings: Savings per car per year: 136 gals × 4/5 = 109 Imp. gal × 88¢/Imp. gal = $96.00
Savings over 3-year life of car ($96.00 × 3 years) = $288.00.
Savings on 224 replacement cars over a 3-year period = $64,500.00.
Average savings per year ($64,500 ÷ 3) = $21,500.

Recommendation: By gradually replacing intermediate-size cars with compacts, a company can cut down on gasoline consumption and save a great deal of money.

Gas-fired door heaters eliminated at receiving dock

The situation: At a General Motors plant, five gas-fired door heaters were used for tempering air when a number of large dock doors were open to receive trucks with raw stock.

Action taken: at a total cost of $2,100, an interior metal wall with two doors and weather curtains was installed at the edge of the receiving dock. Receiving dock sprinklers were converted to a dry system and the five gas units were disconnected.

Energy savings: Gas — 12,800 Mcf × 1.020 MMBtu/Mcf = 13,056 MMBtu
Electricity: 3600 Kwh/yr × .003413 MMBtu/Kwh = 12 MMBtu/yr
Total Btu's saved:
13,068 MMBtu = 13,068 Mcf.

Dollar savings: 13,068 Mcf @ $2.00/Mcf = $26,136/year

Cost of improvement: $2,100.

Recommendation: Consider the use of fixed walls or canvas or plastic curtains or other barriers to limit access of cold air from loading and receiving docks to the plant or warehouse floor. Loading dock shelters which reduce air flow into a heated area also represent an attractive investment. (see case history)

Lift truck tests show cost-saving potential

The situation: The Staff Services department of Kimberly-Clark of Canada Limited decided to perform tests on part of the firm's fleet of propane-powered lift trucks to determine ways of saving money.

Action taken: The project evaluated a portable carbon monoxide analyzer, diagnostic ignition analyzer and an electronic ignition system. Results showed that propane-powered fork lift trucks, equipped with catalytic mufflers and capacitor discharge electronic ignition systems require less maintenance, less downtime, less fuel and give better reliability than standard propane-powered units. Tests also pointed to the possibility that heating and ventilation costs in all of the firm's Canadian plants could be reduced, and that greater protection from fork truck exhaust emissions could be given to plant personnel.

Energy savings: Up to 20% of lift truck fuel costs. For one truck tested at the Rexdale, Ontario plant, fuel consumption was reduced by 20% or 1.58 lb./hr., and since the truck operated for 2,820 hours per year, fuel savings of 4,455 lbs/yr. would result.

Dollar savings: 4,455 lbs/yr. × $0.085/lb. (for propane) = $378.00/year.

Recommendation: Look into the possibilities of installing catalytic mufflers and capacitor discharge electronic ignition systems on propane-powered lift trucks.

Off-peak charging of lift truck batteries reduces bills

The situation: At a General Motors plant, battery chargers for electrically powered fork lift trucks had traditionally been started at the beginning of the first work shift. This practice incurred an additional electrical load at a time of peak demand and resulted in extra demand charges from the electrical utility.

Action taken: Battery charging was undertaken during the second shift — when peak demand is much lower.

Energy savings: None. However, savings on the electrical bill result from the reduction of demand charges.
Previous consumption: 400 Kw at peak demand.
Present consumption: 400 Kw during off-peak demand period.

Dollar savings: $400 \text{ Kw} \times \frac{\$2.00}{\text{Kw}} = \$800./\text{mo.}$
$= \$9,600$ per year.

Cost of improvement: Nil.

Recommendation: Look into the possibility of rescheduling any energy consuming activities which need not be carried out during peak electrical energy demand periods. For further reductions in demand charges, use of a peak load scheduler or "load shedder" should be investigated.

Shelters installed on loading docks

The situation: At an equipment manufacturing plant, a single loading dock was used in which 26 square feet of open area existed between an average truck and the loading dock. Given a relatively long heating season (high degree days) and a substantial differential between average inside and outside temperatures (65° and 40°F, respectively) substantial amounts of gas-fired building heat were being lost unnecessarily.

Action taken: A loading dock shelter was installed which made a tighter "fit" between building and truck and eliminated approximately 85 percent of the 500 fpm air loss.

Energy savings: Previous loss: 26 sq. ft. $\times$ 500 fpm $\times$ 40 wk/yr $\times$ 6 day/wk $\times$ 4 hr/day $=$ 60 min/hr $\times$ .0183 Btu/cf°F $\times$ (65-40)°F $=$ 340 MMBtu/yr.
Savings: 340 MMBtu/yr $=$ 0.85 $\times$ 290 MMBtu/yr.

Dollar savings: 290 MMBtu/yr = 290 Mcf @ \$2.00/Mcf = \$580/year.

Cost of improvement: \$600.

Recommendation: Estimate the energy loss through loading dock doors, particularly if your plant is subject to severe winters. Dock shelters, which come in a variety of designs, can under some conditons pay for themselves in a single heating season. Permanent and temporary walls and barriers inside the loading dock should also be investigated.

"Truck of Tomorrow" claims 35-40% fuel savings

The situation: Aero Mayflower Transit Company put its computer to work to determine whether significant fuel savings could be realized in a tractor-semitrailer moving van combination through use of components designed primarily to reduce the amount of energy required to propel the rig at speeds of 55 to 60 mph.

Action taken: The computer came up with an answer, and a rig called "Mayflower Truck of Tomorrow" was built with the following specifications:

- Air deflector.
- A vortex stabilizer to control sidewinds, attached vertically to the headwall of the trailer.
- A vane mounted on the front edge of the trailer's roof with rounded lip covering the upper edge and an air spoiler above it.

- A special diesel turbo-charged engine coupled with a six-speed transmission and 23,000 lb. drive axle with a ratio of 3.70.
- Fan clutch.
- Steel-belted radial tires mounted on 22″ wheels for the tractor and 8¼-20 steel radials under the tandem trailer.
- Engine governed at 1,950 rpm and pulling the rig at 61-63 mph at 1,800 and 1,850 rpm. Top speed at 1,950 rpm is 66.8 mph.

Energy/dollar savings: The truck regularly gets 8-9 mpg — 35 to 40% better mileage than similar Mayflower trucks without the fuel-saving components.

Recommendation: Take a look at some of the many fuel-saving devices on the market and decide which ones have the most potential for your type of operation. Some measures are better for city driving, some for highway, etc.

Tips for saving energy and money in transportation and delivery

In-plant operations

1. Maintain electric lift truck motors.
2. Charge lift truck batteries during off-peak hours to save on electrical bills.
3. Equip propane-powered lift trucks with catalytic mufflers and capacitor discharge electronic ignition systems for greater efficiency.
4. Install air locks on loading doors. Alternatives are fixed walls, fireproof canvas or plastic curtains and other barriers; or dock shelters on loading docks.

Savings in the use of cars

5. Convert cars in the sales fleet from large or intermediate-size cars to compacts.
6. Buy cars with smaller engines.
7. Cut down on gas-guzzling features such as air conditioning.
8. Make better use of the cars at night by allowing employees to drive the vehicles home if they form carpools.

Saving energy in trucking

9. Consider consolidating routes and making other scheduling and loading changes to make sure that trucks are being used efficiently.
10. Train drivers to be energy-conscious by doing the following:

- Not making "jack-rabbit" starts.
- Not leaving engines idling for long periods of time, even in cold weather.
- Staying 200 rpms under the governor maximum to save fuel.
- Not hitting the governor with every shift, since it takes extra fuel to go to maximum rpm with every shift.
- Keeping a light foot on the accelerator and brake pedals to conserve fuel — not hotrodding or sliding to a stop.
- Gearing down when necessary, rather than lugging. Lugging the engine takes extra fuel, and increases the likelihood of early overhauls and breakdowns on the road.
- Checking tire pressure. Keep tire pressure up —it's easier on the tires and saves fuel.
- Preventing spillage. Make sure extra fuel isn't spilled when refueling. Don't top the tank! Keep the fuel cap tightened so that fuel is not lost through evaporation or spillage.
- Staying alert and rested in order to drive safely and conserve fuel. A tired driver is erratic, doesn't shift gears when he should, and fails to hold his speed. Driving this way uses extra fuel.
- Keeping the engine tuned. An efficient powerplant burns less fuel.
- Sticking to lower speeds. Three methods can be helpful in making drivers slow down:

i. Use a road speed governor;

ii. Use of a tachograph to enforce a fleet speed limit;

iii. Motivating the driver to want to maintain lower speeds, e.g. Sharing truck mileage and fuel consumption data with drivers to encourage efforts at saving.

11. Use the right truck for the right job.

- Make sure the truck is specified correctly and that the engine is large enough.
- Don't retire power units purchased for highway operation to city use since they can't be expected to perform properly.

12. Adhere to a regularly scheduled program of preventive maintenance to prevent major breakdowns — sixty days is a good interval between tune-ups.

13. Use radial tires. They cost more than bias-ply tires initially, but the investment soon pays off in fuel economy.

14. Investigate use of diesel engines, especially in cases where trucks are used for extensive travel.

15. Consider use of aerodynamic drag reduction devices especially on straight trucks.

- Wind deflectors mounted on cab tops to deflect air flow over the top of the van or trailer;
- Vanes which turn the airflow around trailer corners;
- Rounded trailer corners and fairings mounted on the forward flat face of the trailer; and
- Gap fillers to reduce turbulence in the gap between tractor and trailer.

16. Use multiple trailer combinations to increase load space and achieve fuel economy on a productivity basis.

17. Use automatic transmissions to save fuel in local pick-up and delivery operations.

18. Use fan clutches — cooling fans don't have to operate all the time.

19. Engine and drive train modifications can also save energy. They include:

- Derating engine horsepower.
- Reducing engine speed (rpm).
- Reducing the axle ratio.

20. Automatic radiator shutters control engine temperature, and save money by adding to engine longevity.

21. Use self-steering axles to save energy used in negotiating turns.

22. Take a look at fuel additives. Some companies have found that they have a marked effect on fuel economy.

23. Consider optimizing routing in city deliveries. Often, use of computers and operations research techniques can be justified.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x **4.448 222** = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1° = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	$1\,\ell = 1\,dm^3 = 10^{-3}\,m^3$
tonne	t	$1\,t = 10^3\,kg = 1000\,kg$
ångström	Å	$1\,Å = 0.1\,nm = 10^{-10}\,m$
bar	bar	1 bar = 100 kPa
hectare	ha	$1\,ha = 10\,000\,m^2$

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SAVING MONEY THROUGH EFFICIENT PEOPLE MOVING 8

Saving money through Efficient People Moving

Introduction:

In Canada, 75% of Canadian commuters travel to work in automobiles and the average occupancy of these vehicles is 1.4 persons/car. While improving existing public transit systems, and initiating new systems to communities presently without any service is the most obvious alternative to improve work trip load factors, the potential of this alternative is limited. Due to physical and financial constraints public transit cannot be expected to provide a good level of service for all. However, if employers with an enlightened view of energy conservation and employee relations are willing to make the organizational effort to get things started, carpools and vanpools can become an attractive alternative for those who presently commute in low occupancy automobiles.

This booklet deals in some depths with the basics of establishing company encouraged or sponsored vehicle pools and pinpoints direct and indirect benefits for both the employees and the employer. The following is a brief outline of the procedures for organizing carpools and vanpools, incentive and disincentive suggestions, legalities and employer and employee benefits.

Moving people efficiently

The day of the lone driver cruising down the highway on his way to work is coming to an end. The high price of gasoline, the rising value of land used for parking, increasing rush hour traffic congestion and the prohibitive costs of constructing new highways are realities Canadian commuters—and Canadian employers—must begin to face.

More and more people are realizing that individually driven automobiles are energy inefficient, and are wasting precious and finite sources of hydrocarbons which future generations of Canadians will need for other purposes.

The most obvious solution is public transit and, where reasonably good service is available, there are many things a company can do to encourage people to take the bus or the subway. For example, some companies in the U.S. provide employees with a $1 per day or more fringe benefit by picking up the transit fare required to get to work. Other companies use "negative" incentives, such as raising parking lot fees so that driving is even less economical.

If public transit to the plant is inadequate, some companies use another tactic — approaching transit officials to get better service. All-day bus service is not always necessary — sometimes buses at shift change are all that are needed. Companies located downtown may want to encourage transit authorities to put more buses on the main route to the plant, or to provide special bus lanes on congested streets.

But, due to physical and financial constraints there are many work locations which cannot be served well by public transit. Work sites on the periphery of a large metropolitan area, industrial parks, and small town factories frequently fall into this category. And one alternative to the low occupancy auto is shared driving — forming a carpool or a vanpool to travel to work.

Almost everyone is familiar with the carpool, in which a group of employees take turns driving their own cars to work, or in which one person drives and others reimburse him.

Essentially, a vanpool works in the following fashion. An employer, group of employees or citizens purchase a passenger van to transport employees to and from work. Participants pay a subscription rate to cover expenses — amortization, operating costs, maintenance, etc. The driver, an employee of the company, is not usually paid for driving the van but is compensated in other ways — by getting a free ride or reduced fare, or using the van during off-hours. The vans carry from eight to fifteen riders, are larger than station wagons, and smaller than buses.

A successful ride sharing service must be acceptable to people in terms of convenience, cost and door-to-door travel time. And its acceptance requires more than public relations

work — it constitutes a major change in people's habits. An organized effort is needed to co-ordinate programs, to provide effective incentives to participants and to maintain the system once it is put into operation.

Companies can do many things to encourage ride sharing. They can set up a carpool or vanpool program themselves. They can provide incentives to people who form their own ride pools. Or, they can help by publicizing the merits of ride sharing. All of these alternatives are covered on the following pages.

Joint travel in carpools or vanpools provides direct benefits to the employer — cost savings on parking space, improved employee availability and attendance, enhanced morale and good public relations for the company. And these benefits increase proportionately with the numbers of people involved.

Whatever the arrangement, companies should offer encouragement for employees to travel to work together. Experience has shown that without direct encouragement from the employer, only those to whom carpooling or vanpooling is an easy and necessary option will become involved.

Ride sharing options

Simply stated, there are four pool concepts:

- Carpools in which the passengers know each other. Driving can be rotated among the members and no fee charged; or one member can drive every day and the others pay him a fee.
- Carpooling with manual or computer matching. Passengers are matched up according to housing locations. Either of the driving systems mentioned above can be used.
- Carpooling with designated stops at the roadside. Here, pasengers board the cars at these stops and pay a pre-arranged fee.
- Vanpooling. Instead of cars, vans seating eight to fifteen people are used. This concept is feasible if a sufficiently large number of potential vanpoolers live in one district. Vans may be owned by the users or supplied by the company.

Private carpooling is the concept most widely practiced in Canada. The City of Vancouver and the federal government are experimenting in Ottawa with computerized carpooling. The federal program has been quite successful. The initial project was limited to four departments or 8,000 people, and the government has been pleased with the results. The Vancouver program has not been as successful.

Vanpooling has been used successfully by Polysar employees in Sarnia for years. This program involves fifteen vanpools with up to thirty people in each. These people work three different shifts and share in the costs of purchasing and operating a passenger van to commute to work. And Chrysler Canada's Windsor vanpool program, which started early in 1977, involves 12 vans and 118 people. Response has been favorable and Chrysler hopes to expand the program soon. Using the premise that each van takes six or seven cars off the road every day, the company estimates savings of 11,560 gallons of gas or $9,710 in the first three months of operation.

Car and vanpooling are much more widespread in the United States. Washington's National Aeronautics and Space Administration began a carpooling program in 1965 which has increased car occupancy to an average of 3.85 persons per car — compared to the Canadian average of 1.4 persons. In St. Louis, the McDonnel Douglas Corporation promoted carpooling for its 47,000 employees when parking became critical, and doubled car occupancy among workers. At 3M Company headquarters in St. Paul, Minnesota, the company owns the vans used by the employees. The initial six-vehicle demonstration program has been expanded to include 92 vans.

On the surface, vanpooling appears to be an alternative to carpooling, but in practice, vanpools often supplement and do not discourage the growth of carpools. For example, at the 3M Company, 14.3% of the employees engaged in carpooling as early as 1970, but now, in addition to the vanpooling program, over 20% of the employees are using carpools.

One of the most advanced U.S. programs, in Knoxville, Tennessee, sponsored by the Tennessee Valley Authority, includes express buses, carpooling and vanpooling.

How everyone profits from pooling

Carpooling and vanpooling benefit both the company and employees. The company wins in a number of important ways:

- Cost savings on parking spaces. Statistics show that 85% of employer-provided parking space is free for the employee. Based on suburban, ground level parking, construction of one parking space may cost a firm $400 to $600, while maintenance, snow removal and taxes cost an additional $20 per year. Costs for high-rise downtown parking can be much higher. Carpools and vanpools decrease the need for parking space and free valuable land that could be better used for expanding industrial or office space.
- Reduced congestion. In most large companies, a great deal of time is wasted in parking lot tie-ups. Car and vanpools can help ease the strain on commuters and make them more productive after arriving at work and before leaving at the end of a shift.
- Employee availability. Ride sharing has been a traditional form of transportation for employees who drive great distances to and from work. It can be a way to tap an otherwise unavailable work force. Polysar Ltd. cites this as a main reason for the Sarnia program's existence. Some of the vans running at the 3M Company program in St. Paul, Minnesota serve low income areas where there is no adequate transit system, and commuting by car is financially prohibitive.
- Improved employee attendance. Car and vanpooling can have indirect benefits in the form of employee attendance. Peer pressure often makes lateness practically nonexistant. And on bad weather days during severe winter months, the same peer pressure will encourage employees to show up rather than stay home.
- Enhanced morale. Car and vanpoolers who don't have to drive, arrive at their jobs more relaxed and prepared for work. A company car or vanpooling program also fosters greater company loyalty, and frequently sets the company in the public spotlight as one which is making a positive effort toward solving energy problems. Better employer-employee relations can also result. As an example, the 3M Company has a vice-president riding with clerical staff in the same vanpool — a situation that provides an ideal opportunity to break down the traditional lack of communication between the two groups.

And the benefits are not limited to company management. Among the "pluses" for employees are:

- Fuel savings. Gas costs over a dollar a gallon in many parts of Canada, and more price rises are coming. As costs continue to rise, fuel savings are increasingly important.
- Monetary savings. Vehicle operating costs are cut in half when two people share a car, and if four people are in one pool, each spends only a quarter of the operating costs a lone driver would incur. Parking fees, if applicable, are also cut.
- Reduction of road congestion. The present operating occupancy of a private commuter vehicle in Canada is 1.4 persons per car. If this occupancy could be raised to 3.0, the number of vehicles would drop by half. Imagine the difference this would make on Toronto's Don Valley Parkway, Ottawa's Queensway or Montreal's Decarie Expressway!
- A car at home. Car and vanpooling allow other members of the commuter's household to use the car during non-use periods. Days when the commuter rides with another driver, other family members can make daytime trips for shopping, appointments or social events. In some cases, the need for a second car can be eliminated.
- Improvement of the environment. As fewer cars travel on less congested roads, air pollution is reduced. Stop and go traffic, caused by people driving to and from work during rush hours, is the worst offender in terms of pollution.
- Comparable travel time. Only pick up time is added to the trip, and this is negligible where people live in the same area or along the main route to work. In addition, many carpools and vanpools are given priority parking, and time can be saved in walking from the parking lot to the work area.

How much can I expect to save?

The answer is that it really depends on the number of persons in your pool. If, for example, you previously drove alone and there are now four others in your pool you may save as much as 80% on gas or parking fees from your previous commuting costs. The type of car you drive must also be considered when calculating the actual saving. And you should also consider savings on the wear-and-tear items such as tires, batteries, brakes and filters. It all adds up to a substantial saving over your normal operating expenses. And think how nice it would be not to have to drive every day. The tables below and on the right provide a breakdown of the national average costs of operating certain types of cars. They will provide some guidance to how much it really costs you to run your car.

A guide to car operating costs

The question of how much it costs you to operate your car is very difficult to answer. Personal records provide the only really accurate means of calculating the cost. However, the following figures derived from the Canadian Automobile Association publication "Car Costs 1976" will provide a helpful guide.

Costs per mile

Standard size domestic car with automatic transmission:

Fixed Cost	Variable Cost	Total
15.5 cents	8.3 cents	=23.8 cents

Sub-compact with standard transmission:

Fixed Cost	Variable Cost	Total
9.4 cents	5.3 cents	=14.7 cents

Fixed Costs include fire and theft, collision, property damage and liability insurance; license and registration and average annual depreciation costs.

Variable Costs include such items as gasoline and oil, maintenance costs and tires.

Car insurance

Although I.C.B.C. states that you are not legally required to carry insurance beyond the applicable minimum, it is strongly recommended that you obtain not less than $500,000 third-party liability coverage. For your own security, please check with your insurance agent before carpooling.

YOU SAVE WHEN YOU CARPOOL

Here's an example of what it costs annually for a 20 mile daily round trip to downtown Vancouver if you drive a standard size car with automatic transmission:

1. Multiply (23.8 cents) × (20) cost per mile, miles per day	=	$ 4.76
2. Add daily parking cost	+	$ 2.25*
		$ 7.01
3. Multiply by number of working days per year	×	240
4. Equals cost per year to drive alone	=	$1682.40

**typical Vancouver all day parking rate.*

Calculate what it costs *you* to drive your own car to work each day:

1. Multiply *(your cost per mile) × (your round trip mileage)	=	$
2. Add daily parking cost	+	$
3. Multiply by number of working days per year	=	$
	×	240
4. Equals your cost per year to drive alone	=	$

**insert 23.8 cents for standard size; 14.7 cents for sub-compact; or the actual per mile costs for operating your own car.*

Here's what you could save on the *variable costs* alone:

1. Multiply *(your variable cost per mile) × (your round trip mileage)	=	$
2. Add daily parking cost	+	$
3. Total variable cost	=	$
4. Divide by the number of people in the carpool	÷	
5. Equals the cost to you if you carpool	=	$
6. Your minimum daily saving is the difference between 3 and 5	=	$
	×	240
7. Minimum annual saving	=	$

**insert 8.3 cents for standard size; 5.3 cents for sub-compact; or the actual variable costs for operating your own car*

Remember that by pooling you might completely eliminate the need for a second car, saving you perhaps an extra $1,000 (depending, of course, on the car). Consider these savings. Ease the squeeze—it pays to pool!

The advantages of ride sharing are numerous, from everyone's point of view. Once the company has decided to promote ride sharing, it has a number of options — carpooling, vanpooling or provision of incentives for employees.

Carpooling

Everyone is familiar with the carpooling concept. And many people have even participated in carpools at one time or another — when one father drives all the boys to scouts; when friends agree to ride together to the club every Wednesday night; or, as we're suggesting, when a group of people go to work in the same car.

The simplest carpools are those in which all the passengers know each other and where arrangements can be made among the passengers themselves. In some cases, the driving is rotated among the carpoolers and no payments are made. In other cases, the driver is the same person each day, and the passengers pay the driver. Combinations of the two systems are also possible. When the passenger-run carpool is encouraged, the company's role is limited to providing incentives to participants.

The alternative — "dynamic" carpooling — requires more effort and organization on the part of the company. Here, the employer matches potential carpoolers, manually or using a computer. As for the actual driving, either of the two systems mentioned above can be used. Another alternative is designated stops at the roadside, where passengers board the car and pay a pre-arranged fee.

Make ride-sharing fun for everyone.

Follow these ten simple rules for carefree car pooling.
We made them simple so that we could understand them.

1. **Think about others.**
   Like marriage, staying together is far more difficult than simply getting together in the first place. Be honest with one another. Some poolers are great conversationalists, others are duller. Seek the middle ground. Don't hog the heater or the chatter. If you enjoy a good Havana join a smoking club, if you want to share a ride, be considerate of your pooling partners.

2. **Get organized.**
   Know what to do if someone breaks a leg or finds some other feeble excuse for not going to work. After calling a doctor, remind George that he is the reserve driver. Decide beforehand who to call if arrangements have to be changed.

3. **Sharing the costs.**
   Decide on the cost sharing arrangement when you have your first get-together. Use the example in the folder to calculate your share of the cost. Then fix a pay-day and stick to it.

4. **Who drives?**
   In some pools, the same person drives almost continuously. Trust her. She likes driving (as a child, she made brr-mm, brr-mm noises). Other pools prefer to alternate drivers, with each person taking a turn. Do what suits you best but establish the driving schedule well in advance.

5. **Where to meet?**
   Big Julie's is a good spot, but the parking lot is the usual meeting place for the drive home. In the mornings, try to keep the number of stops down by choosing pick-up points convenient for more than one passenger.

6. **Decide your route and timetable.**
   Find a good route and stick to it. The CP right-of-way along East Boulevard is not recommended. It's too bumpy. If someone fails to show up, certainly wait for a minute or two, but keep in mind that a long wait may make three people late instead of only one.

7. **If you have a 'dropout'.**
   Don't panic. We have a sister who is one and it isn't contagious. Keep in mind that Commuter Club is willing and able to find a new member for your pool. Contact your Commuter Club Coordinator or Commuter Club Headquarters for assistance.

8. **Good housekeeping.**
   The occasional vacuuming may turn up a dollar or so in change. Don't tell anyone. Use it for a car wash. And, apart from a weekly clean-up, make sure that the car safety items are regularly inspected.

9. **Straight home; no side trips.**
   Errand running and carpools mix like prunes and gravy. Shopping trips should be confined to more suitable times.

10. **Drive safely.**
    Seriously…

From Vancouver Commuter Club brochure

Dynamic carpooling has several advantages over the basic system. Even if the idea of carpooling occurs to a commuter, it can often be difficult to establish an acceptable carpool among associates due to distances between residences. By enlarging the universe of potential matches to include more employees, the carpool information gathered under the dynamic system can bring together more commuters with similar travel needs.

Implementing a program

Once a company has decided to start a carpool program, it should appoint a group of people or committee to head the implementation of the project. This group should be a combination of middle and upper management and employees. Ideally, the people in the group should have a personal interest in energy saving, air pollution and traffic congestion, since their enthusiasm is bound to rub off on others. This group's job is to motivate company employees — through coffee klatches, circulars, bulletin board board advertisements, etc. If in-house publications such as newsletters, trade or union papers are available, they can also be used effectively to publicize carpooling.

Much of the program's success depends on initial publicity. Potential carpoolers must be made aware of the advantages and details of the program. If the budget permits, brochures, pamphlets, posts or stickers can be used to achieve this initial impact.

The City of Vancouver's carpooling program, for example, involves a pamphlet called "Car Pooling, What's In It For You?" It describes how to save money by joining the "Commuter Club", how to join, and provides an application form. The brochure even includes a section on carpooling etiquette.

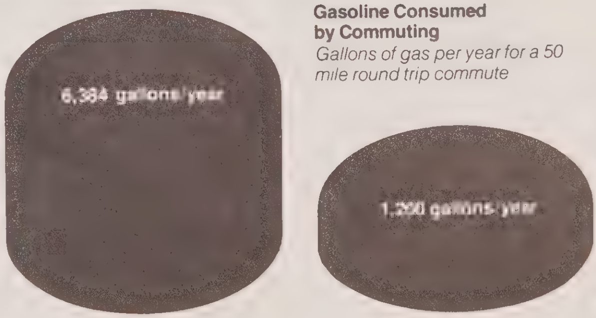
The Ontario government has published a booklet called "Car Pooling Makes $ense" for its program. The federal Office of Energy Conservation provides a brochure as well as a poster with the caption "Save Cash and Fuel in a Pool".

Another key to an effective carpool program is use of incentives (see section on incentives for details). Many incentives are doubly effective when combined with a company-sponsored or "dynamic" carpool program — priority parking spaces, free parking, provision of vehicles for carpoolers, automobile operating cost incentives, gasoline tax rebates and working hour incentives. Disincentives to the low-occupancy auto, such as higher parking charges, can also be used effectively.

Another kind of "perk" can be provided when passengers do not know each other — to help overcome the change-of-habit problem and to reach the person who is relucant to drive to work with a bunch of total strangers. For example, matchmaking schemes often try to match non-smokers as an inducement to relieve the anxiety of those who do not like to ride in a crowded vehicle with smokers. Face-to-face meetings can be arranged on company time for potential carpoolers to get acquainted, and employers or sponsors should assure potential carpoolers of the safe driving habits and records of the participants.

Gasoline Consumed by Commuting

Gallons of gas per year for a 50 mile round trip commute



8 cars with an average 1.4 commuters per car (15 m.p.g.)

1 vanpool with an average 11.2 commuters (10 m.p.g.)

Matching carpoolers

The mechanics of setting up a carpool involve four stages: promotion collecting information, matching people involved, and distributing information regarding suggested pool combinations.

Each employee should receive an application form with a covering letter, brochure or booklet explaining the program. Meetings can be held to clarify any questions. And every employee's response should be sought with the understanding that the application does not commit him to participation. Often, if returns are made through employee supervisors, the

response is greater than if they were just mailed in to a committee. With a higher percentage of returns, a greater number of acceptable matches is possible. And many programs carried out in this way have obtained a 90% employee response.

The data needed depends on the extent of the program. Where the program serves one major parking and employment area, the essential data may be limited to name, home address and business telephone number. Time of arrival and departure are included where shifts or staggered starting times exist. Additional questions may be included such as the person's desire to drive only, ride only, or share driving; and his preference of smoking or non-smoking companions. Information concerning present mode of travel to work can be solicited as well. However, an easy-to-understand, short data form will get the best response.

Data can be matched manually or by computer. Generally, where there are fewer than 300 potential applicants, a hand matching or manual technique is easy and inexpensive. Application forms are given different numbers, and these numbers are plotted on an area-wide map. Visual inspection will suggest acceptable carpools based on location of applicants. However, other variables such as working hours, driver only / passenger only preference and non smoking / smoking preference can also be considered.

The computerized approach to carpool matching is usually based on either a grid system, census tracts or traffic analysis zones. The home and work locations of participants can be input into the program by manual identification from grid maps or through automatic address coding. A computerized program based on a dual density grid system such as the Canadian Burroughs or Postal Code system or the one developed by the U.S. Federal

APPLICATION

Please complete this questionnaire, even if you are not sure that you want to join a car-pool at this time.

1. A (1) **Name** (3)
Fill in number
1 = Mr.
2 = Mrs.
3 = Miss
4 = Ms.
Last Name 18 19 20 Initials

2. Address
21 Number Street City 50
51 Nearest Street Intersection 65 66 Postal Code 71 72 75 76 79

3. B **Work address**
1 2 Office Address Section Room No. 18 19 Department 25

4. Telephone
26 Work 32 33 Local 36
OR
37 Home 43

5. Smoker — Non-Smoker Preference
45 **Fill in number**
1 = non-smoker
2 = smoker

6. Drive/Ride Preference
46 **Fill in number**
1 = drive only
2 = ride only
3 = share driving

69 73 74 78 79 80

7. Work hours
I work from: 47 : 51
to: 53 : 57

Example:
from: 0 8 : 3 0 A M
to: 0 4 : 3 0 P M

8. How do you get to work? 63
Fill in number
1 = drive alone
2 = drive with others or passenger (car-pool)
3 = bus
4 = other

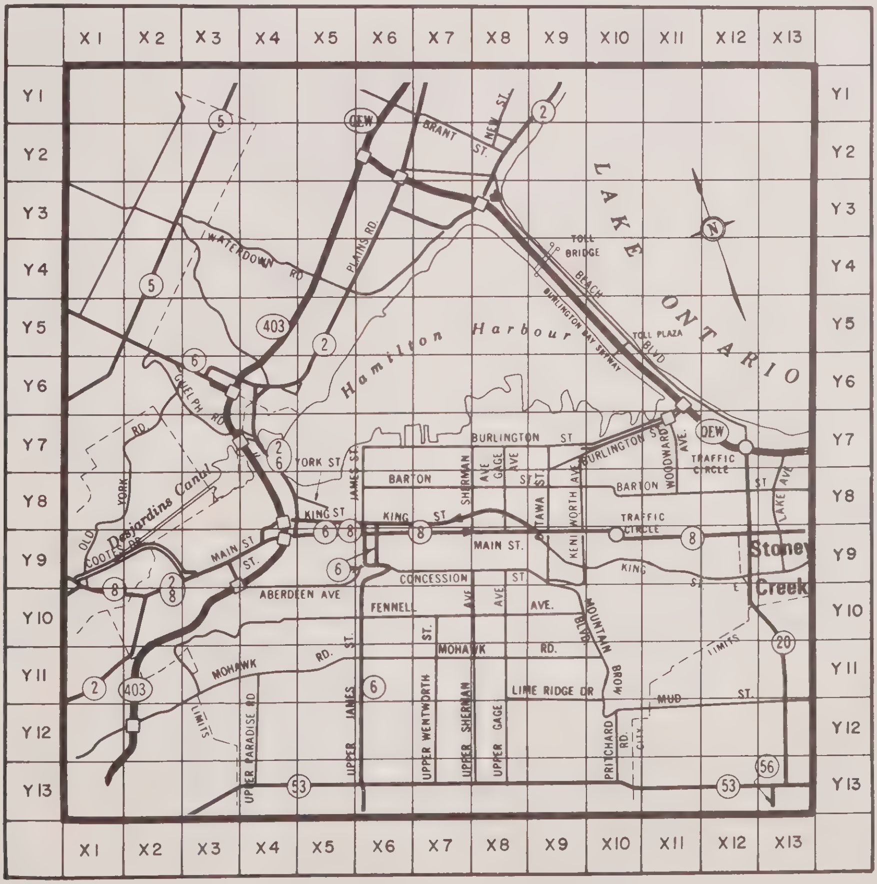
If you pool, how many others are in your pool? 64

9. In which language would you prefer to receive correspondence? 65
Fill in number
1 = French
2 = English

Highway Administration, provides a comprehensive approach to carpool and buspool matching. This type of program can handle multiple work locations and multiple work times simultaneously, but separately. A federal government computer program will soon be available to any employer requesting it.

A critical variable in any matching system is the correct size of land area for grouping suggested pools. Total door-to-door travel time is significant, and generally when the total travel time for all ride sharers falls within a 25 percent increase over the fastest alternative, it constitutes an acceptable pool. Experience also indicates that one-square-mile areas are acceptable for gathering carpools in higher density regions, while areas ranging to four or more square miles are acceptable in less dense regions.

Distance from the employment source should also be considered. Operational experience in the U.S. has shown that a high percentage of those who travel long distances (greater than 10 miles one way) to work who don't have public transit available to them would join a pool if the opportunity arose. And a U.S. study concludes that 20% of those who commute 10 to 15 miles (one way) and 25% of those who commute 15 to 20 miles would choose to be car or vanpool participants if given the chance. When driving time is more than 45 minutes, commuters may accept driving to a specific residence or pre-determined parking area where carpools originate. The potential combinations are many, and any reasonable grouping should be suggested, allowing the individual to make the final selection.



GRID MAP FOR CARPOOL MATCHING

Example: If you lived in Stoney Creek at the junction of Highways Nº 8 and 20 your grid would be X12 – Y9.

After potential matches are selected, distribution of information may be handled in several ways including personal contact, mail and master lists. However, personal contact is usually the most successful method. One way is to bring together 50 to 100 of the potential carpool members for a "coffee hour", an extended regular coffee break in which people discuss special arrangements for forming new carpools. The informal session could start with a "pep talk" on the carpool program, followed by questions. Carpool listings could be distributed before or during the meeting and a master list maintained at selected points for further reference.

Mailing or intenal routing systems can be used along with the personal contact method, or where the personal contact method is not feasible.

In some cases where employees are constantly working on different shifts, the matchmaking process must be far more flexible, since employee combinations will differ from week to week. One way of solving this problem is use of a pegboard. The Sarnia vanpool operation uses this method. Each member of the pool has a plastic disc with his name, address and telephone number on it. The disc has a hole in the middle and fits over a peg. A pegboard is set up as a matrix of eight columns and three rows, and commuters place their pegs in the columns to indicate when they are coming in. The driver for that shift sorts out the discs on the section of the pegboard pertaining to that particular trip, puts them in order of pickup and thus determines the route.

In the Chrysler of Canada program the problem of vanpoolers working on different shifts is solved by grouping all the people who work straight days into a few vans, and by ensuring that the people in the other vans are given the same shifts at the same time.

Maintaining the program

Once the carpool program has begun, it is important to maintain or increase the occupancy rates derived from the initial matching effort. One way to make sure people are happy with the program is to send around a questionnaire to participants to get indications about deficiencies in the program and how to attract new participants.

Vacancies will still exist in some carpools and others will develop quickly due to people moving or changing jobs. A final phase in a comprehensive carpool program is provision of readily available master lists which are periodically updated. To be effective, the availability of this service must be made known to all employees.

The frequency required for updating information depends on factors such as rate of employee turnover and number of employees involved. Existing personnel records and parking permit applications can be helpful in the updating process. It may be possible to have new employees indicate their willingness to participate in the program by having them fill out matching forms at the time of personnel processing. Arrangements to obtain changes in employee addresses and phone numbers should be explored.

As new applications are received, all names can be compared and corrections made as well as including new names. Or, in the case of computer matching, when a sufficient number of changes are obtained from these sources, the computer card deck can be updated and the entire program run again to produce a new master listing.

Where access to existing data is difficult, a periodic resurveying of all employees can be used to maintain an up-to-date list. While this approach requires more effort, it provides an opportunity to show management's continuing support of the program. It also provides a chance to refine the surveying process on the basis of experience gained the first time around.

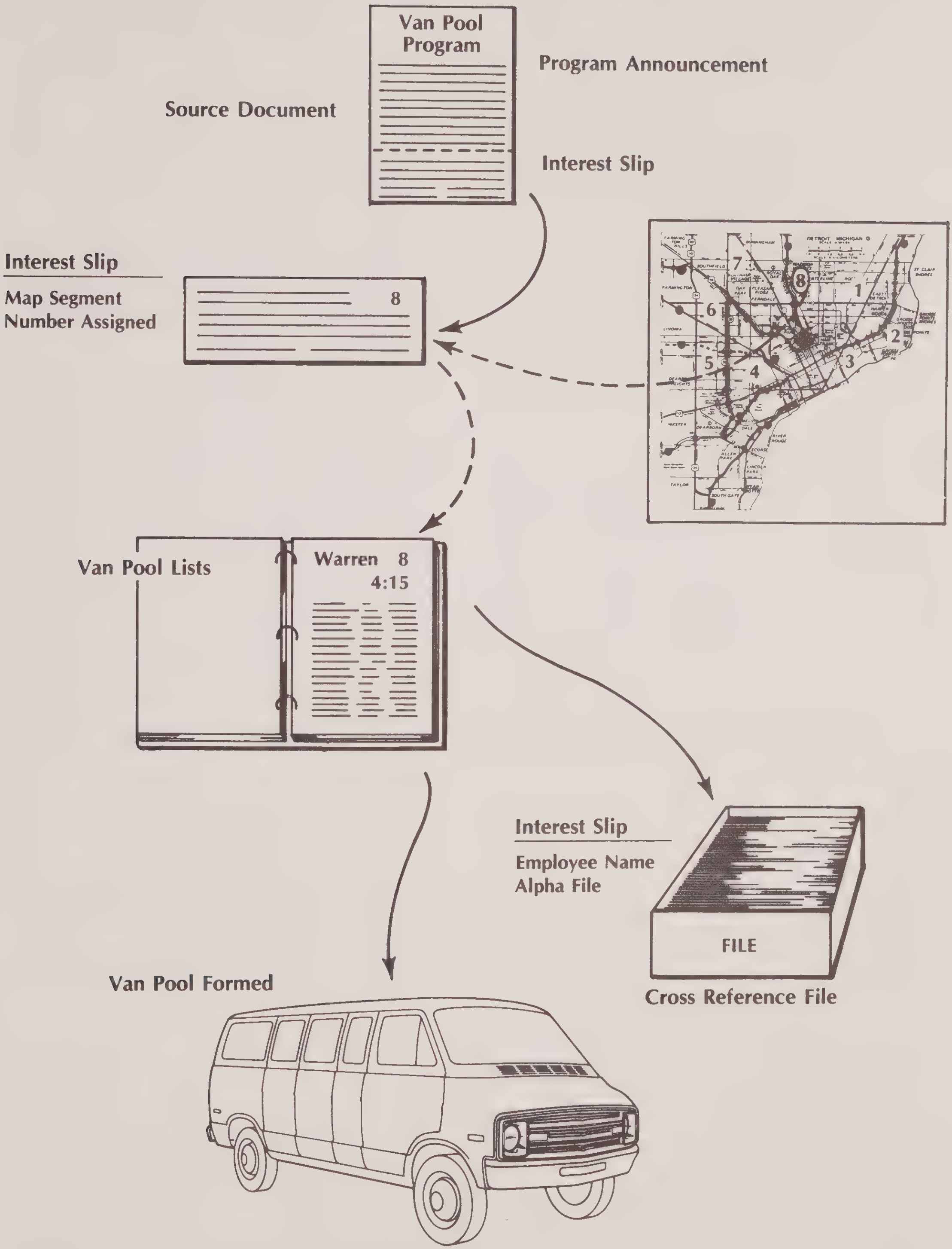
Vanpooling

Since each van takes more cars off the road, vanpooling is even more efficient than carpooling in reducing energy use, traffic congestion and air pollution.

An obvious advantage of vanpooling over carpooling is that employees do not have to use their own cars for driving to and from work. At the same time, vanpooling retains the convenience of door-to-door pickup and offers some of the virtues of a bus — including a regular driver and more freedom for the passenger to choose where to sit and how to use his travel time.

Vanpools can be used to take employees from

Flow Chart,
Manual Matching Method



outlying areas into the city. But they are equally suitable for use in industrial parks and periphery areas which are not well served by bus service. One established criterion is that vanpools are most feasible when the route length is greater than 8-10 miles each way.

In practice, the company has several options as to the degree of its involvement in a vanpool program. Certainly, it can administer the whole program — taking responsibility for purchase of vans, insurance, publicity, etc.

And if the company purchases the van, the purchase price is merely a loan since it will be recovered through employee fares. And an additional stimulus for vanpooling may be provided in the near future if the federal government decides to institute guaranteed loans for van purchases.

However, the company may feel it is preferable to have the vans owned and insured by individual employees, existing employee associations (e.g. credit unions) or commuter clubs formed for this purpose. This makes it possible for the firm to initiate a vanpool program without direct financial involvement in its operation. Employee ownership also may reduce the company's risk exposure. At the same time, some statement of company backing may help employees obtain more favourable finance or leasing charges.

For example, the Polysar Employees Credit Union in Sarnia, Ontario helps each of its members commuter associations purchase vans and provides central accounting services. Operations are handled individually by each van's association.

The company should decide at the outset which steps it wants to initiate and which should be left to the van owners. It might decide, for example, that a company vanpool administrator could best provide the survey and promotional services in the program's early stages and can suggest guidelines for driver and rider selection. The rest can often be left to each individual pool.

Whether a community association is formed, or whether the company purchases the van, a few members are designated as driver/co-ordinators. The members of the vanpool pay to ride — usually on a per month basis — and the fee is set to cover purchasing expenses and costs of running and maintaining the van. Drivers do not pay to ride.

Fares may be collected by the driver, deducted from the payroll or billed to the passengers. In addition, the driver may be allowed additional benefits: to keep fares collected after the breakeven points have been reached (most companies calculate breakeven point as involving eight to ten passengers for a 12 passenger van); to use the van on weekends, paying a fee to the company based on mileage used; or to have an option to buy the van when it is retired from the fleet.

Some firms even lower van fares by using their vans for business or as inter-plant shuttles during the work day. In turn, the department using the van pays the van account a mileage rate.

Organizing a vanpool program

Most firms start their vanpool programs with a few pilot vans in order to test out their operating policies and employee acceptance. In almost every case, the programs have been enthusiastically received, as shown by waiting lists and groups that form for new vans. Existing evidence shows that if management backs vanpooling, employees will participate. In addition, once an employee starts vanpooling, he or she is likely to stay with it — the major problem is overcoming the initial apprehension.

Before plunging into a vanpool program, the company may want to determine the demand for such a service. A sample demand survey form is included.

One of the misconceptions about vanpooling is that it involves hefty administrative duties. In fact, the best way to run a vanpooling program is by using as little paperwork as possible. Once the program is running, it should take very little administrative time. For example, the huge 92-van 3M program in the United States requires the time of one and a half people.

Naturally, the first step in implementing a vanpool program is to appoint someone to manage it. Vanpool programs are typically administered by people from the transportation, personnel or administrative services departments. And once the vanpool program administrator has been appointed, he should confer with all the appropriate staff organizations — legal, accounting, personnel, insurance, etc. — to obtain agreement on the details of administering the vanpool program.

Commuter Van Pool Interest Survey

I am interested in becoming a member of a Commuter Van Pool.
I would like to be a

☐ **Driver** ☐ **Passenger** ☐ **Either**

Name ______________________________

Address ______________________ City ______________

Nearest major cross streets ______________________

CIMS __________ Office Phone No. __________ Start Work ________ Leave Work ________

MAIL TO: Mr. Tom McDonald CIMS: 416-15-22

Decisions must be made as to buying or leasing of vehicles. Some employers prefer to purchase their vans because of the total control this arrangement offers in terms of internal cost management. Purchasing may offer a great opportunity for company support of specific cost items. A lease cost automatically includes items such as excise and sales taxes, finance charges and the lessor's own business expenses

A method of establishing rates must also be determined along with a way to collect fares. The driver can collect the fares, or payroll deductions can be used. If payroll deduction is chosen, appropriate forms and a method of processing are required. An alternative is having the driver bill each passenger at the beginning of every month. The passenger then pays the required amount to the cashier. This last alternative has merit since it relieves the driver of the responsibility and potential problems of collecting and handling money.

The following specifications are suggested as requirements for vans:

- 12-15 passenger van
- 300-360 cubic inch engine
- front and rear heating
- 3-speed automatic transmission
- power steering and power brakes
- 8.75 x 16.5, 8-ply tires or equivalent
- outside low mount mirrors

In addition, all vans should be equipped in accordance with provincial safety regulations.

As with carpooling, publicity for a vanpool program is very important. Program announcements should be prepared and circulated, along with a reply form to be sent through employee supervisors indicating interest in becoming a rider or driver-co-ordinator, (see carpool section for ideas).

One of the best ways to publicize the program is to offer incentives. Several companies in the U.S. offer free demonstration ride periods. Such an incentive can be the key element in starting a program since studies show that once an employee starts vanpooling, he will stay with it. Another good way to publicize the program is to park a sample van in front of the building with a sign stating the advantage of vanpooling.

Van Pool Lists

WARREN

#8
4:15

Name	Office Ph.	Major Cross Streets
S. J. JONES	6-5142	Garfield & 13 Mile Rd.
T. M. THOMAS	6-3728	Moran & 13 Mile Rd.
B. L. ALLEY	6-2061	Kelly & 12 Mile Rd.
V. O. AKERS	6-2742	Sims & Kerby

Other incentives, (see incentives section) are also applicable.

Interested employees should be grouped into vanpools. Both manual and computer-matching techniques are also applicable here.

Once a list of prospective riders and driver / co-ordinators has been compiled, a meeting should be held with interested employees at which time the proposed program is explained and questions answered.

Prospective driver / co-ordinators should then be contacted and evaluated on the basis of: a safe driving record; a valid driver's license and the willingness to apply for the correct class of license required in the province; a job not normally requiring travel or overtime; a low incidence of absenteeism or tardiness; and a recommendation by his supervisor (optional).

The drivers chosen should be presented with the names of potential vanpoolers from their area of residence to assist them in organizing a vanpool and be given vanpool sign-up forms and payroll deduction forms (if applicable) to be completed by the potential vanpool passengers. Because of the nature of their responsibility, the driver / co-ordinators should sign binding agreements (see page 17).

Driver / co-ordinators should be briefed as to the operator's manual and insurance and accident procedures. Additional safety measures include provision of drivers with St. John Ambulance training, and having two drivers in the van.

The program administrator should arrange for delivery of vehicles to driver / co-ordinators. When the drivers and passengers have been selected for a particular vanpool, the exact daily round trip distance, including passenger pickup and delivery, should be calculated. Commuter fares can then be established.

Maintaining the vanpool program

The program administrator's job is not over once the program is set in motion. As in the case of carpools, information on vacancies and new vanpoolers should be maintained (see carpool section).

Vehicles should be inspected periodically for both appearance and operating condition. The maintenance of the vehicle should comply with the instructions in the owner's manual. Periodic meetings should be held with driver / co-ordinators to exchange program information and provide communication between the drivers and the company management.

The program administrator should receive and review monthly each driver / co-ordinator's revenue and expense report. He should check to see that authorized payroll deductions are being processed and that receipt totals balance each month. He should authorize payment of program expenses (lease or purchase payments, insurance, etc.) as the invoices are received, and report vanpooling program status to company management on a monthly basis. In addition, the program administrator should serve as a clearing house for comments, complaints and information on the commuter van program.

There are, of course, no "hard and fast" rules, and the suggested format is just that. Its purpose is merely to provide and guide and show considerations involved in implementing a vanpool program.

Company incentives

There are several ways in which a company can encourage car or vanpooling without actually setting up a program. However, the company must be careful that incentives are not looked upon as discriminating against those employees, who through no fault of their own, are not able to participate in either vanpools or carpools. One of the best ways, is to establish priority parking spots for carpools — cutting a few minutes off the commuter's travel time and often saving him a cold walk through an open parking lot. The most common procedure for implementing preferential parking is issuing stickers which are applied in a visible spot on the vehicle, permitting easy identification of unauthorized cars, either at point of entry or during patrols of parking areas.

Enforcement should also include some method for inspecting incoming or outgoing vehicles to be sure that the vehicle is indeed carrying the number of persons specified. This incentive is most successful when employees can perceive a distinct advantage to themselves over their fellow employees who do not carpool, not merely a marginal improvement over an existing parking situation.

Another incentive is free parking. A recent survey of the employees at the King County assessor's office in Seattle, Washington indicated that free parking was nearly twice as effective as other methods in encouraging carpooling. (Conversely, raising the rates for everybody in the parking lot also provides an excellent incentive for carpooling!).

Another possible incentive is provision of vehicles for carpoolers, in cases where the company has a pool of vehicles used to conduct company business. Frequently company vehicles are returned to a garage or lot at the end of the day to remain idle until the next morning. This capital equipment could be more effectively used by allowing employees to drive the vehicles home at night if they form carpools. And such a program is operating at the Arkansas State Highway Department in Little Rock, Arkansas. Here, state vehicles carrying a minimum of three carpool riders are permitted to be taken home at night.

Automobile operating cost incentives, gasoline tax rebates, and working hour incentives are also available to the company looking for incentives. The latter could take the form of slightly reduced working hours or shift rotation preference for carpoolers, provision of flexible working hours, or encouraging the maintenance of normal working hours so that employees will not be subjected to overtime and can meet their carpools. This last method has been used effectively at the Pentagon in Washington, D.C.

Shell Canada Limited came up with an innovative way of encouraging its employees to carpool. During Ontario's Energy Conservation Week, October 31 to November 6, 1976, Shell offered to donate $5.00 to the United Way for each of its employees who returned an enclosed card stating that during that week he engaged in one of the activities listed on the card. One of these activities was carpooling. The program lasted only a week, but on a larger scale with, perhaps, a more modest financial incentive, this type of program could promote carpooling and at the same time provide good public relations for the company.

Checking the legalities

Vanpooling and carpooling — against the law? Not as a rule. But be sure to check with municipal authorities and provincial transportation departments before proceeding with a program. Legalities such as insurance requirements or competition with buses and taxis have posed some problems for car and vanpool programs.

But as the ride-sharing concept becomes more widely recognized, many provinces are taking steps or are expected to take steps to change applicable legislation. When the City of Vancouver decided to institute its Commuter Club program, the provincial and municipal authorities acted very quickly to change the legislation regarding car and vanpooling. And the Ontario government is currently investigating the legal issues related to ride-sharing — with a view toward changing legislation.

In the meantime, look into the following areas before you start your program:

- Check with the appropriate authorities. After the intended program has been drawn up, regulatory bodies should be contacted. Sometimes more than one authority is involved, as in large municipalities such as Toronto and Vancouver. Even in some smaller cities, approval must come from provincial departments before traffic and other by-laws can become effective. Cover yourself and your program by contacting both municipal and provincial authorities.
- Drivers licenses. In most carpools, drivers do not require special licenses. However, vanpool drivers responsible for large numbers of people normally need special licenses. Check with the provincial transportation department for details.
- Taxi regulations. In some provinces, carpool vehicles can be classified as taxis depending on the wording of the law. Check with municipal authorities to make sure this is not the case. In Quebec, check with provincial authorities responsible for taxi legislation.
- Exclusive franchise rights of transit systems. The attitudes of transit authorities to car or vanpools vary. In Sarnia, the transit company considers the vanpool associations a complementary service. However, the London, Ontario Transportation Commission prevented a private service from operating between the University of Western Ontario and some of its colleges on the basis of exclusive franchise rights. The Sarnia attitude seems to

be the norm. Nevertheless, it is wise to check with the transit authorities.

- Insurance. In provinces which have no-fault insurance, in the event of an accident, a carpool passenger will be able to claim whether or not the driver of the vehicle was at fault. But problems can arise in other provinces. When payments are made in a carpool, the passengers are not considered "guest passengers" and are not covered by standard insurance. Drivers of carpool vehicles must take out additional insurance to cover their liability to these passengers. Vanpool operators require special insurance as well.

  Because members of a carpool are said to be acting in a joint enterprise, it is often mistakenly suggested that an injured passenger cannot sue the driver. Under the law, this simply is not so. If drivers of carpool vehicles are covered by insurance, it is unlikely that an injured third party would want to sue a passenger in a carpool vehicle. However, if this happens, passengers are not liable for the negligence of the driver.

  One problem could arise if the driver did not have sufficient insurance coverage. The insurance company could then go to other members of the group so that their insurance could cover the accident.

- Employer liability. Employees are generally not covered by the various workmen's compensation schemes when travelling to and from work, even if the transport is provided by the employer. If time spent travelling is included in the terms of employment, compensation coverage generally does apply.

  An employer can be liable to the public for the negligence of another employee under what is called "vicarious liability", but the employer is liable only if the workman was negligent in the course of his employment. Here are three common cases:

1) When the employer hires a bus and provides a driver, he is responsible—since the driver was employed for this purpose.
2) When the employer is covered by workmen's compensation at the time of the accident—since it occurred during working hours.
3) When the carpooling vehicle is owned by the employer, he can sometimes be responsible—since owners of motor vehicles in all provinces are liable for damages caused by that vehicle, and are responsible for ensuring that the vehicle is in good repair.

- Personal liability. When does an employer become so involved in providing carpooling activities that he becomes liable on a personal basis for injuries caused to a participating employee? A decision on personal liability is usually based on whether it was or should have been contemplated that someone would be injured by your actions. Questions then arise as to whether the type of injury was forseeable or too remote. It is difficult to indicate at which point an employer will make himself liable; each situation depends on the facts.

  The employer's involvement in matching schemes could cause a case of personal liability. If the employer matched people with a driver with a bad driving record, for example, he could be held responsible. Another case for personal liability might be if an employer did not properly maintain a vehicle.

It all sounds rather ominous. But it isn't really. A little forethought and a chat with company lawyers and outside agencies generally sort out potential problems in short order. The benefits of carpooling and vanpooling far outweigh the costs of a few hours spent to assure that a program is properly established.

Ride sharing — good public relations

No matter which approach a company chooses — encouraging public transit, providing incentives or actively setting up a carpool or vanpool — the results will be positive. As gas prices go up, employees will start looking for ways to economize and will become more responsive to ride sharing. The fact that the company is promoting something that will save gas and money is good public relations.

The response to any of these programs may not be overwhelming at first. But keep at it. With rising gas prices and congested traffic, ride sharing is the trend of the future. Why not get in on the ground floor?

APPENDIX I

Chrysler Commuter Van Program Operating Agreement

This Agreement between the Driver/Coordinator whose signature appears below and Chrysler Corporation (hereinafter called "Chrysler") shall become effective on the date it is accepted by Chrysler, as evidenced by the signature of its authorized representative in the space provided below for this purpose.

For the purpose of forming and operating a van pool with a minimum of nine (9) passengers, Chrysler agrees to furnish the use of a 12-passenger van, to assist in forming and maintaining the van pool and to render such other reasonable assistance as may be required for the functioning of the van pool. The Driver/Coordinator will be the primary driver of the van during the term of this Agreement.

The Driver/Coordinator agrees to be responsible for the following in connection with the operation of the van assigned to him:

1. Maintain a valid state driver's license (and/or chauffeurs' license, if required) for operating a van.

2. Drive the van to and from his Chrysler location and pick up and deliver the other Chrysler employees who pay to ride with him.

3. Keep the passenger pool for the van at or above the minimum of nine (9) paying passengers.

4. Arrange for service and fuel for the van and clean the vehicle inside and out as needed.

5. Train a back-up driver to insure daily operation of the van.

6. Supply a secure place for "at home" parking of the van, preferably in a locked garage.

7. Keep a record, satisfactory to Chrysler, of the operation, expense and income of the van.

Chrysler agrees to reimburse the Driver/Coordinator for his out-of-pocket expenses in the operation of the van to and from work along the prescribed route and to pay over to the Driver/Coordinator 50% of any fares received from passengers in excess of the required minimum of nine (9). Chrysler will report to appropriate taxing authorities any amounts paid to the Driver/Coordinator for passengers in excess of nine (9), and it will be the responsibility of the Driver/Coordinator to include such amounts on his individual tax returns.

The Driver/Coordinator will be permitted to use the van during off hours. Chrysler also agrees that the Driver/Coordinator may, as an inducement to the person who agrees (as provided below) to serve as back-up driver, make the vehicle available for use by the back-up driver at the same rate and under the same terms as applicable to the Driver/Coordinator, as set forth herein. The back-up driver also must maintain the required state driver's license for operating a van, and loss of his license will result in his automatic removal as back-up driver.

Chrysler reserves the sole right to decide if the off-hour use of the vehicle is proper and does not become excessive as to type of use or mileage.

It is agreed that the following regulations apply to the operation of the van:

1. Operation of the unit is permitted only by the Driver/Coordinator and back-up driver and by the spouse of either of them, if properly licensed. Only under emergency conditions will any other person be permitted to operate the vehicle. In this connection, in the absence of both the Driver/Coordinator and the back-up driver, any Chrysler employee that is a member of the van pool may operate the van for pickup and delivery of passengers to and from work if he is authorized to do so by the Driver/Coordinator and is properly licensed.

2. The vehicle is to carry no passengers to and from Chrysler facilities, other than Chrysler employees.

3. In the case of personal use, the carrying of passengers other than Chrysler employees and members of the immediate household of either the Driver/Coordinator or the back-up driver is permissible as long as it is not on a regular basis.

4. The vehicle is not to be used for a trip beyond a one-hundred (100) mile radius of the Driver/Coordinator's home without specific advance written approval from Chrysler.

5. The vehicle is not to be used to carry passengers or freight for hire, for ride sharing or any other purpose involving pay for transportation, other than the specific purpose of the Chrysler Commuter Van Program.

6. Use of the vehicle to pull trailers is not allowed. No trailer hitches, temporary or permanent, are to be attached to the unit.

7. The vehicle is to be driven only on hard surfaced public streets and highways and other normal access roads and driveways, and is not to be driven off normal roads, on frozen lakes and rivers, or in any other manner that would expose the vehicle to unsafe conditions.

8. The vehicle is not to be driven over bridges posted for a maximum weight of 3 tons or less.

9. The Driver/Coordinator is responsible for promptly reporting any accident involving bodily injury or property damage. Such reporting is to be in accordance with the procedures outlined in the Auto Accident Information Kit, which is to be in the glove compartment of the unit at all times.

   a. Such reporting is also to include injury to a passenger in the van even though no other party is involved. (This would include such cases as a person falling inside the vehicle or injuring himself while entering or alighting from the vehicle.)

   b. The Driver/Coordinator will be responsible for completing and filing the appropriate state motor vehicle bureau accident report as well as the Chrysler automobile accident report (Form ______).

10. Any traffic violation involving the van are the responsibility of the driver. The Driver/Coordinator and back-up driver are to report promptly any traffic violations to Chrysler.

This Agreement may be terminated by either party on thirty (30) days written notice delivered to the other party in person, by telegram or by mail. In addition, it will terminate automatically on (a) termination of the Driver/Coordinator's employment with Chrysler, (b) loss by the Driver/Coordinator of the required state driver's license or (c) breach by the Driver/Coordinator of the terms of this Agreement.

____
Driver/Coordinator

Accepted:

Chrysler Corporation

By ______________________________

Date ______________________________

Agreement to Serve as Back-up Driver

I have received a copy of the above Operating Agreement, have read it and agree to be bound by its terms in serving as back-up driver to the above Driver/Coordinator. I understand that breach of such terms will result in automatic termination of my right to serve as back-up driver.

Signature	Commencement Date	Termination Date
1. ______________	______________	______________
2. ______________	______________	______________
3. ______________	______________	______________
4. ______________	______________	______________

APPENDIX II A Typical Fare Calculation

Depreciation Cost

Depreciation per month for 40-mile round trip		$ 133.00
Insurance Cost		105.00
Administration Cost		
Costs incurred by Commuter Transportation Services, Inc. for administration of Van pool Program		25.00
Monthly fixed costs (based on 40 miles)		$263.00

Operating Costs ($ per mile)

Gasoline	$	0.10
Lube, minor maintenance	$	0.02
Tires, brakes, battery	$	0.01
Miscellaneous	$	0.01
Total Operating Cost	$	0.14

Total monthly operating cost is determined by the number of miles involved × 260 working days × 14¢ per mile divided by 12 months = monthly operating costs.
Operating costs for a 40 mile round trip .... $ 121.00

Individual Fare

Individual fare is determined by dividing the total monthly cost of the vehicle by eight (the number of passengers in each vehicle) .... $ 48.00

Tips on saving energy and money through efficient people moving

Organizing a Carpool Program

1. Appoint a committee to head implementation of the project.
2. Determine the details on how the program will be administered, and what incentives and/or disincentives, if any, will be adopted.
3. Motivate employees using one or more of the following procedures: Conduct information meetings with time set aside to answer questions, distribute circulars, attach brochures with paycheques, post information on bulletin boards, etc. All publicity should mention incentive program if one exists.
4. Distribute application forms. Application form should provide a place where employee can indicate whether he/she wishes to be a driver/passenger or just a passenger. To ensure employee does not "forget" to fill in the form, the form should state that it is to be returned to his/her immediate supervisor by a specified date, regardles of whether he/she wishes to participate.

5. Collect application forms.
6. Match manually or by computer. (Note, the Federal Government has a computer matching program soon to be available on request.) In cases where employees work different shifts, investigate the use of a pegboard to accommodate the need for more flexible carpooling systems.
7. Notify employees re pool they are in. Allow for some flexibility, if an employee wishes to be in another pool.
8. Maintain the program by periodically updating master lists and informing any new employees about the program.

Organizing a Vanpool program

1. Appoint a committee to head implementation of the project.
2. Determine
   a) whether vans will be purchased or leased.
   b) type of insurance required
   c) legalities
   d) fare calculation procedures
   e) fare collection procedures
   f) driver arrangements
   g) rules for vanpool participants
   h) whether there will be an incentive program, and if so what incentives will be offered.
3. Advise union officials, or employee representatives of your company's intentions.
4. As vanpools are a relatively unknown concept in Canada, employees must be fully briefed about how the concept works before any meaningful employee survey can be conducted. Meetings should be held not only to explain the concept but also to explain the advantages to employer, employees, and greater community. If incentives program should be mentioned, if one exists.
5. In addition to the meeting, one or more of the techniques described in carpool procedure #3 may be used.
6. Distribute application forms. Application forms should provide a place where the employee can indicate whether he/she wishes to be a driver/co-ordinator or just a passenger. To ensure the employee does not forget to fill in the form, the form should state that it is to be returned to his/her immediate supervisor by a specified date, regardless of whether he/she wishes to participate.
7. Collect application forms, and compile lists of riders and prospective driver/co-ordinators.
8. Match manually or by computer — see carpool procedure #6.
9. Contact and evaluate prospective driver/co-ordinators.
10. Select driver/co-ordinators, and provide each with a list of participants in his/her pool.
11. Calculate participant fares for each pool and brief driver/co-ordinators on fare collection procedures.
12. Sign agreements with driver/co-ordinators.
13. Sign agreements with pool riders.
14. Purchase or lease vehicles and arrange for delivery to driver/co-ordinators.
15. Maintain the program — see carpool procedure #8.

Incentives and Disincentives Suggestions

1. Establish priority parking for carpool and vanpool vehicles.
2. Provide free or reduced parking fees for pool participants, and/or raise the rates for low occupancy vehicles.
3. Give automobile operating cost incentives to carpoolers.
4. Provide working hour incentives for carpoolers—slightly reduced working hours, shif rotation preferences, flexible working hours or encouragement of maintenance of normal working hours so that carpoolers will not be subject to overtime and can meet their pools.

Checking the legalities

1. Check with outside agencies and company lawyers to make sure of the legalities of such things as drivers licences, taxi regulations, exclusive franchise rights of transit systems, insurance, employer liability and personal liability.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg\cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	$N\cdot m$	J
Power	watt	J/s	W
Electric charge	coulomb	$A\cdot s$	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	$V\cdot s$	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	$cd\cdot sr$	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x **4.448 222** = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	$N\cdot m$
Viscosity-dynamic	pascal second	$Pa\cdot s$
Thermal conductivity	watt per metre kelvin	$W/(m\cdot K)$
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	$J/(mol\cdot K)$

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1° = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY IN OFFICE PRACTICES 9

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SAVING MONEY IN OFFICE PRACTICES 9

Saving money in Office Practices

Introduction:

The many small but important energy saving measures that can be carried out in an office add up to a potentially large reduction in energy consumption.

Dealing less with heating, cooling and lighting — which are covered in other booklets in this series — this booklet deals more with the myriad of other "do's and dont's" that make for an energy efficient office environment.

An energy-saving plan for the office

When you think of cutting down energy use in the office, a few obvious (and important) things come to mind — turning off lights, turning down thermostats and turning off electrical equipment when not in use, are the standard ones.

But saving energy and money in office practices goes much further than that.

Think, for example, of all the paper that is used in the office each day. By examining ways to cut down on paper use, a great deal of energy can be saved — energy used to manufacture the paper, energy used to ship it, and for that matter, human energy used to file, read and store it. Money can be saved as well — money used to purchase paper, money paid to people who file it, money spent on filing cabinets to store it, and money needed to rent or buy office space to accommodate the filing cabinets.

Energy and money can also be saved by changing the existing setup at the office. Some companies have cut down working hours to save on heating and lighting; others have reduced use of elevators; and still others have taken down partitions in the office so that air can circulate more freely.

The savings to be gained by a particular office energy conservation program often aren't large, but they are significant and most cost very little — frequently nothing — to implement. They have the added benefit of making office employees aware of energy conservation. In many cases, they also increase the efficiency of office operations.

Take a look around the office to see where energy can be saved. The dollars that can be saved — and the areas in which they can be saved — may surprise you.

The office environment — heating, cooling, ventilating, lighting, water

A major contribution to the present high rate of energy consumption in buildings has been the emergence of engineering technology and equipment which provides sophisticated space environments. Quite naturally, the building occupants have become accustomed to the new environmental standards — bright ambient lighting; heat at a uniform 72°F, summer or winter; 50% humidity; high rates of ventilation. In a manner similar to the auto industry, the trend was to standards that consumed more and more energy. Use of energy per se is not bad for the economy. Without it we would not have been able to enjoy the standard of living we now have. However, the problem is that a large proportion of this energy is being wasted, and it is this energy wastage which must be reduced or eliminated.

Now the trend has been checked, and in some cases reversed. But it will take time to change the habits and minds of the people involved. Energy conservation does not mean discomfort (there is ample evidence to show that a reasonable environment can be achieved at acceptable levels of energy consumption). However, there is a need to keep people informed of reasons for energy conserving measures so that they will greet changes more favourably.

Saving energy through heating — more than turning down thermostats

Turning down the thermostat — to 68°F during the day, and 63°F during the night and on weekends — can save a good deal on an office heating bill. The Office of Energy Conservation estimates that turning the heat down to these temperatures from 72°F saves about 15% on the

Per cent annual fuel saving with 5°F (3°C) night setback

(Based on eight-hour period)

City	Percentages
Halifax	6
Montreal	5
Ottawa	4
Toronto	6
Hamilton	5
Winnipeg	2
Calgary	3
Edmonton	2
Vancouver	7
London	5

average heating bill. By turning the thermostat even lower at night, greater savings can be effected. One study indicates that by setting the thermostat back 10 degrees at night, savings of 19.8% can be effected in Toronto, and 23.5% in Vancouver.

One way to make sure the heat is turned down at night is to install a dual thermostat/timer system. Here, a time circuit is wired up in which a seven-day central timer activates a "night thermostat" each evening and on weekends. There is a manual override at the burner to allow janitorial staff or people working late to leave the thermostat on the "day" setting. Automatic, timed controls, remove much of the "human factor" for the control of energy conservation, and can be counted on to pay for themselves in short order. They also have other applications, among them, lighting, air conditioning, and ventilation.

When the air distribution system is poorly designed, resulting in drafts, it is hard to maintain lower space temperatures. It is sometimes necessary to balance or improve air distribution in order to achieve comfortable conditions at lower temperatures.

Employees aren't always enthusiastic about temperature changes. In fact, when the thermostats are first turned down, workers often feel cold. The best advice here is to explain the situation. Let employees know, for instance, that for every degree above 68°F, 2½% more energy is consumed.

Discourage the use of space heaters since they use large amounts of energy. Suggest that the dress code might be relaxed a bit so that employees can wear sweaters, slacks and other comfortable clothing.

But savings can be increased in other ways. Take a look around the office. Make sure your thermostat is in a good location, away from any drafts or sources of heat which may cause a false reading. If the thermostat is near a heat source, it may be shutting off before the correct temperature is reached. And if a draft is making the area around the thermostat cool, you may be wasting energy by heating to more than the required temperature. If this is the case, consider moving the thermostat.

Drapes — especially lined ones — help insulate windows and stop drafts. Drapes should be closed at night, since both the material and the dead air between the drapes and the window provide insulation. For extra savings, some companies install drapes lined with foil to make greater use of the principle. However, when the winter sun is shining, open the drapes and let solar heat supplement the heating system.

Make sure nothing is blocking sources of heat. If drapes are covering baseboard heaters, shorten them. Make sure office furniture is not blocking heaters, preventing the free flow of air.

Sometimes partitions stand in the way of air flow, and rooms are poorly heated. Consider removing partitions to make sure air can circulate more freely, if partitions are keeping the heat from reaching some areas of the office.

On the other hand, barriers can be used effectively if only some parts of the office are to be heated. Keep the doors to unused rooms and storage areas closed, if those areas don't have to be heated. Zone control is helpful in this respect. If there are thermostats in every room, turn them down in the rooms that don't require heat. Consider installing zone controls if some areas of the office don't have to be heated.

Frequently a little capital outlay can go a long way. One of the best examples of this is spending a little money caulking windows and weatherstripping doors to keep the heat in. It virtually always pays off.

Another way to save energy in heating is to make sure the heating system is in good shape. Most of the energy waste in a furnace or boiler can be attributed to the amount of air being supplied for

combustion and to the condition of the heat transfer surfaces. Too much air reduces the efficiency of the combustion process and wastes fuel; too little air does not permit the complete combustion of the fuel and also leads to higher bills. A scale deposit of 0.012 inches thick inside a boiler tube reduces the rate of heat transfer by as much as 45%. Soot deposits on heat transfer surfaces also reduce the rate of heat transfer and result in fuel waste. Schedule or contract for regular maintenance on furnaces or boilers to ensure efficient operation.

Keeping cool in summer

Air conditioning isn't as much of a concern as heating in our Canadian climate, but there are still more than a few weeks in the summer when keeping cool — either by an air conditioning system, or just keeping out the sun's heat — is a very vital function.

Air conditioning is a big energy user — and the best way to save that energy is to avoid using it if possible. Use fans — preferably ceiling fans — not only are they cheaper, they also use less energy than air conditioning.

Fans do little to reduce humidity, and they don't remove dust or pollen from the air. But the heat waves we experience in Canada are seldom of long duration — something to keep in mind when deciding whether to invest in an air conditioner.

There are other ways to keep cool. Encourage employees to wear light clothing in summer. Don't use appliances — photocopiers, electric typewriters, etc. — unless you have to. They too generate heat. Turn out the lights where possible since they generate heat as well.

Remember that some of the same principles that apply to keeping heat in during winter, apply to keeping heat out in summer. Insulation is one of the best ways to keep heat out. Keep doors and windows closed during the hot part of the day if it's cooler inside. But, if there's a breeze, open the windows since circulating air feels cooler. Keep drapes closed during the day. Light drapes and blinds are especially helpful since they reflect the sun's rays and can reduce solar heat by as much as 50%.

Think about installing awnings, sun screens, panels, overhangs or reflecting window films. The latter can reduce heat gained through windows by as much as 80%. Phoenix Mutual Life Insurance Company in Hartford, Connecticut experimented with reflecting films on windows, and saved about six percent on cooling (see case history). Reflective coatings can be a viable alternative to installation of additional, expensive air conditioning. If your office has storm windows, leave them on in the summer to keep the heat out, providing they can be opened to let breezes in when it is cool outside.

If it is decided that air conditioning is needed, there are still a number of ways to reduce your energy bill. Make sure your air conditioner is the right size for the office, i.e. the one that uses the least electricity for the required amount of cooling. Check the Energy Efficiency Rating (EER) — a measure of the amount of cooling achieved in relation to the amount of electricity used. EER is determined by dividing the Btu per hour rating of an air conditioner by the watts of power it uses. The higher the EER, the more efficient the unit and the less power it will consume. The information needed to calculate the EER can be found on the information plate on the machine. U.S. made air conditioners carry a tag showing the EER, and Canadian models must now carry a CANTAG label showing the EER and the range of EERs on available units of the same cooling capacity.

The temperature setting for the air conditioner should be as high as possible without creating discomfort — 78 to 80° F.

During cool periods in the summer, turn off the air conditioner and open the windows to save energy. But let employees know they should never have windows open while the air conditioning is on. This adds a major load to the system.

Make sure the air conditioner is well-maintained. The three to five percent of the cooling investment required to maintain the system in good working order will return 20% in energy savings, extended equipment life, and critical breakdown repair costs.

In small buildings, it is probably more economical to contract for air conditioning maintenance. Require the contractor to have a scheduled maintenance plan written especially for your building before signing an agreement. And, if you use your own maintenance staff, insist on use of an organized, preventative maintenance program.

The automatic timing devices

Time switches are simple, rugged energy saving devices. The proper type of switch should be selected for optimum results. The specific needs of the installation must be considered in order to gain the timing flexibility required.

Several types are available:

1. **24 Hour Dial**
   This controls the same on-off times daily and would, as an example, be used where security lighting is necessary seven days a week.
2. **Skip-a-Day**
   This 24 hour unit provides the same daily on-off times, but can skip selected days when not required. Suitable for commercial or industrial applications with no occupancy on weekends or holidays.
3. **Seven-Day Dial**
   Provides seven-day control with the flexibility of different on-off times for each day (and the skip-a-day feature for selected days of the week). Used in store interior lighting where daily hours vary.
4. **Photo-electric Sun Switch**
   The Sunset-to-Sunrise dial functions in this fashion. At sunset the lights are turned on and remain on until sunrise or any pre-set hour. Mainly used where security lighting is necessary. This unit is designed to adjust to the daily change in the sun's schedule automatically.

Selecting the right timing device

Care in the selection of the timing device is recommended to assure the flexible control of the interior or exterior lighting system to meet your energy saving needs. Discuss the installation of timing devices with a qualified electrical contractor to assure best results. They save energy, time, manpower and money. Installing the correct timing device for your lighting system will result in savings of energy and future operating costs.

Some tips on air conditioner maintenance:

- Clean dust and dirt off inside and outside coils before the summer starts.
- Be sure the blower and electric motor are lubricated, and follow other manufacturer's recommendations.
- Check the tension on the fan belt in a central forced air system — you should be able to press it down between ¼ and ½ inch. If it does not meet these requirements, change the tension by moving the adjusting screws found on the mounting frame that fastens the motor to the blower housing.
- Check the filters on the unit and clean or replace them where necessary.
- In a central cooling system, the filters should be checked once a month.
- During the winter, either remove window-mounted units or seal the window, or seal the unit on both sides with plastic, wood or

a piece of styrofoam. Tape it up well so that cold air won't infiltrate.

- Install seven day timing devices — similar to the ones used on heating systems — to make sure the air conditioner is not running all night or all weekend.
- If the air conditioning system is a central system with control based on either terminal reheat or dual duct, it may be economical to convert to "variable-air-volume". In most cases, such a step would require a consultant's study.

Ventilation

Excessive ventilation air is one of the biggest energy-wasters in offices. Current codes are ambiguous, but they often require 7.5 to 10 cubic feet per minute per person of outside air — air that has to be heated or cooled, humidified or dehumidified, cleaned, deodorized and moved. All that takes energy.

To cite a parallel, in submarines as little as one cubic foot per minute (cfm) is sufficient. Given that figure, in some buildings a reduction to 5 cfm per person is feasible — representing a 33% to 50% cut in energy use. In one case a 10% reduction saved 1.74 MMBtu/yr per 1,000 cfm of system capacity. In general, good engineering practices should be applied based on local conditions to determine the minimum amount of outside air which must be admitted into the ventilation system. And before reducing ventilation, local code authorities should be consulted; but approval is generally granted on the basis that the system can be easily returned to original volume should the reduced air intake prove unsatisfactory.

3M Canada's London office saved $16,000 per year, simply by installing timers on ventilation and air conditioning fans. Areas served by these fans were unoccupied during the night and on weekends, and seven-day timers were installed to control the required run time of the various fans.

Energy-wise lighting

There is a common misconception that leaving lights on saves more electricity than turning them off and on again. In the vast majority of cases, this is simply not true. There is a momentary surge of power when a light is turned on, but it is equal to only a millisecond or two of lighting time. "Turn off the lights" is one of the maxims of energy conservation. Train your employees to switch off lights, even when they are leaving for only a short time (15 minutes or more) and energy savings will result.

It's hard to measure just how much energy can be saved by having employees turn out lights for short periods of time. However, an experiment at one U.S. company shows definitively that turning out lights for short periods of time does save energy. The experiment involved a plant, not an office, but the principle is the same. This company decided to try turning out lights during a one hour lunch break. And, as in many cases, this company was concerned that the savings in electrical energy consumed by extinguishing the 1000 fluorescent light bulbs might be outstripped by costs incurred due to shorter lamp life. Turning off lights at lunch time saved

Sticker fits over light switches

the company $548 per year. Turning off lights, even for short periods of time, is an excellent — and profitable — habit to acquire.

In Europe, some buildings have timers on light switches on stairways, for example, which keep the lights on for very short periods of time. As people walk up the stairs, they can turn on the

lights at each floor, but after about a minute, the light is automatically turned off. This idea shows just how extensively the idea of switching off lights for short periods of time can be used.

Help your employees achieve these savings by putting signs on light switches reminding them to turn lights off. Make sure light switches are highly visible. Consider the idea of changing panel switching for large work areas to wall switching for smaller areas — allowing employees to leave on only the lights that are required. Although it costs a few dollars extra for wiring and switching, energy savings will result.

Lights should also be turned out when the building is not in use. By turning off lights between 10:30 at night and 6:30 in the morning and on weekends at its main office, except in areas which require security lighting, Dominion Foundries and Steel Limited of Hamilton, Ontario saved 3 million Kwh / year or about $75,000 at current utility rates. Significant amounts of money can be saved in reduced fluorescent tubes alone. And turning off lights when buildings are not in use is a highly visible conservation measure. If both top management and employees are given realistic predictions of how much can be saved, this measure can be tapped as a valuable motivational tool.

And if you want to be with the trends, look into "task lighting" — it's definitely the wave of the future. In essence, it means lower overall lighting levels for the office, with smaller lamps directly on the work area to provide higher illumination only where required. It's a concept that will save money.

In the past, the general practice has been to light office buildings uniformly at 150 footcandles per square foot — or five watts per square foot. This level is not needed. Public Works Canada recommends 50 to 75 footcandles for task lighting and 30 to 50 footcandles for general lighting. Even if the highest recommended level — 75 footcandles — is used for the whole office, savings can be substantial. If the illumination level is reduced from 125-150 footcandles to 75-100 footcandles by removing tubes from fixtures, taking care not to leave unused ballasts energized, a saving of as much as 30% can result.

And savings can be even greater if levels are reduced even more in certain areas — cafeterias (when not in use), storage areas and elevators to name a few.

There are a few basic rules to follow when making changes to a lighting system:

- Provide an overall ambient level adequate for a majority of the tasks.
- Provide additional lighting where tasks require levels higher than the ambient level.
- Where the lighting system is modular, attempt to orient work stations to obtain highest contrast rendition in task lighting.
- The ambient lighting level must assure luminance levels for all surfaces in the field of view necessary for sight comfort i.e. luminance relationship between different areas in the field of view must be such that adaption required by the eyes as they change from a field of one brightness to another does not produce discomfort and fatigue.

One maxim which is being discarded is the idea that high light levels discourage burglars. Keeping the lights on all night wastes electricity and helps a potential thief to find quickly what he wants to steal. Premises can be more effectively protected by installing a sonic or electronic burglar alarm which consumes very little electricity. Another solution is to light aisles just enough to spot an intruder from the outside, if the area is patrolled.

12 IES Lighting Recommendations

1. Design lighting for expected activity (light for seeing tasks with less light in surrounding non-working areas).
2. Design with more effective luminaires and fenestration (use systems analysis based on life cycle).
3. Use of efficient light sources (higher tumen per watt output).
4. Use more efficient luminaires.
5. Use thermal controlled luminaires.
6. Use lighter finish on ceilings, walls, floor and furnishings.
7. Use efficient incandescent lamps.
8. Turn off lights when not needed.
9. Control window brightness.
10. Utilize daylighting as practicable.
11. Keep lighting equipment clean and in good working condition.
12. Post instructions covering operation and maintenance.

Dominion Foundries and Steel Limited had already reduced lighting substantially at its main office building by switching off all the lights at night and on weekends, except those required for security purposes. But the company decided to cut even this lighting to one quarter its former level per year to achieve further lighting savings.

Timers should be installed wherever possible to ensure that they are shut off at night, but there is really no substitute for employees who will flick off the switch when light is not needed. Aid them as much as possible. Make sure there are enough light switches so that lights *can* be switched off in unused areas.

Maximize daylight with fenestration and colour

Maximize daylight for illumination, and to complement electric illumination.

"Daylight is not free", according to lighting specialists, but that was truer yesterday than today. Improved reflective, double-glazed, low transmission and insulated glass has removed most of the heat loss disadvantage of earlier years. And, the excellent fenestration available today, plus the use of sun screening, shades, and blinds, aids in controlling incoming solar heat.

So utilize the daylight fenestration makes available. Reflect and deflect light further into the interior of the building with venetian blinds (can also be used to reduce glare) and light coloured surfaces.

Harness colour to save energy. Light, bright, highly reflective colours can increase illumination drastically. As one designer days, "You can't buy the extra 15 foot candles for what it costs to paint the ceiling." In one installation, repainting the ceiling, walls, and floor and refinishing the furniture boosted average illumination from below 10 foot candles to above 40. Capitalize on these IES recommended surface light reflectance values for schools and offices (top limits were chosen to minimize glare):

Ceiling finishes	*80 to 90 per cent*
Walls	*40 to 60 per cent*
Furniture	*25 to 45 per cent*
Office machines and equipment	*25 to 45 per cent*
Floors	*20 to 40 per cent*

As a final thought, light finishes or colours on ceilings, walls, floors and furnishings brighten a room because 90% of the light is reflected from the surface back into the room to reinforce the original light source. Similarly, high intensity decorative wall lighting consumes large amounts of energy and should be restricted in favour of other decorative techniques to produce aesthetically pleasing effects.

Using water efficiently

In most offices, hot and cold water account for only a very small percentage of energy consumed. However, this small amount of energy is important since appreciable savings can be made in areas where water is used — washrooms, kitchens and drinking fountains.

One simple way to cut down on energy is to make sure that water in washrooms is not being heated to too high a temperature. Water is normally heated to 140 or 150°F, a temperature that is too hot to handle. By lowering the temperature to 120°F, savings of 15 to 20% can be achieved. In washrooms, the temperature can be set even lower — to 100°F which is the minimum required for washing hands.

Kitchens require hotter water, and money can be saved by boosting the water temperature locally, rather than heating storage tank water to the temperatures required. For example, if 180°F water is needed for commercial dishwashers, energy can be saved by reducing the storage tank temperature to 120°F and using a booster heater near the dishwasher to achieve the 60° increase. If the installation is sizable, consider installing a small heat exchanger to preheat incoming water by using the heat of the dishwater effluent.

Consider relocating the water heater so that it is as close to the point of use as possible. The longer the run, the more hot water sits in it cooling down between periods of hot water use.

Maintenance is also important. Inspect the water supply system and repair all leaks, including those at the faucets. Enlist your employees' support in reporting leaky faucets and have them repaired as soon as possible. One drop of water per second equals 650 gallons of water per year — a waste of 380 cubic feet of natural gas. (Unnecessarily hot water helps to wear out tap washers more quickly — causing leaks and

higher maintenance costs.)

Inspect and test hot water controls to determine if they are working properly. If not, either regulate, repair or replace them. Check insulation on storage tanks and piping, and repair or replace it as needed. Sometimes significant savings can be gained by increasing the amount of insulation installed on hot water pipes and storage tanks, or replacing the existing insulation with a type that has a better R factor.

There are many ways of limiting the use of water. Shut off domestic hot water circulating pumps during hours the building is not occupied, either manually or using a time clock. Many pumps operate automatically on a thermostat and run continually.

Methods of limiting hot water from taps include installation of spray type faucets with flow restrictors, and use of spring activated hot water taps.

Drinking fountains are often a waste of water and energy. Consider replacing free running drinking fountains with spigot types which use a paper cup. Up to half the water drawn by free-running fountains is wasted.

Standard Tube of Canada Limited found that refrigerated drinking fountains save money. Workers at its Woodstock, Ontario plant would wedge faucet handles in the "on" position to ensure cold drinking water by continuous water flow. As a remedy, the company installed 17 refrigerated coolers providing a substantial water use saving offset slightly by the cost of refrigeration. The company expects to save $1,700 per year.

Sangamo Limited in Toronto found a unique way to save water in its washrooms. By means of a simple adjustment to urinal dump valves in men's washrooms, flush cycles were cut from 42 per hour to 20 per hour with no effect on sanitary conditions. The estimated savings are $1,800 for the first year. The cost . . . nothing.

Changing routines to save energy

Heating, cooling, ventilation, water and lighting are not the only areas in which office energy savings can be achieved. Frequently, changes in office routine can be effective in saving energy. Consider the amount of lighting and heating required for the average office, and how much of this energy could be saved if the length of time required for heating and lighting the building were cut down.

This can be done in several ways. One Canadian company has cut working hours from 8:30 to 5:00 to 8:30 to 4:30 by reducing the lunch hour from one hour to half an hour. Most of the employees were very pleased with the change. And reduction of office hours meant a reduction in heating and lighting costs.

On the other hand, many companies encourage flexible working hours so that employees are not caught in rush hour traffic on the way to work. This system uses more heating and lighting in the office, but fuel is saved outside the office.

Working on the principle that reduction of working hours saves energy, Detroit Diesel decided to have janitorial services performed during the day shift so that lights could be turned off at the end of the shift. Previously, the service began at the end of the day shift, requiring office lights to be left on until 2 a.m., needlessly consuming energy. The energy saved amounted to 2,500 MMBtu/year at a value of $5,000 per year. In some cases, it is not practical to have janitorial and service functions carried out during office hours, but even if only some are scheduled earlier, the energy and dollar savings can be substantial.

In cases where the janitorial staff must clean the offices after hours, energy could be conserved if employees were instructed to turn off the lights when they have completed their job and the janitors were told to turn off the lights when they have completed their job. In some instances it is standard practice for the lights to be left on until the janitorial service is finished — often until the early hours of the morning.

Using office machines less

Photocopiers, electric typewriters, adding machines, coffee pots, vending machines and water coolers are some of the machines found in offices that use up energy. Substantial savings can be gained by shutting these machines off when not in use. For instance, one company with 11 water coolers and 8 vending machines saved almost $200 a year by shutting these machines off at night.

Take an inventory and decide whether you really

need some of the frills — wouldn't manual pencil sharpeners do just as well as electric ones? Do you really need an electric-powered stapler?

Check and see whether people are using individual electric soup pots or kettles to boil water for coffee. Discourage these. It is much more economical in terms of energy to have a central coffee depot with a coffee pot and a kettle, or to use central vending machines.

Elevators can be great energy wasters. Encourage employees to take the stairs for short trips — to walk one floor going up and two floors going down is the rule used by people in the federal government.

Other ways of cutting down on elevator use include reduction of use after office hours — closing down one elevator completely, for example. Some companies have installed demand devices whereby the elevators will answer calls only if a certain number of people need the service. And, if the office is large enough, elevators can be fixed so that they go only to certain floors.

The paper jungle

Whether your company produces tires, furniture, or steel, one of its main "products" is paper — files, memos, photocopies, books, reports, invoices and letters. Paper is not normally associated with energy consumption. But think of all the energy required to make the paper and to ship it; the human energy needed to process it, read it and file it; the energy required to build the filing cabinets to store it; and the money and energy required to build storage space to house the filing cabinets. Paper is an energy user. And the sad part is that much of the paper used in offices today is unnecessary.

The statistics become more real when quantified. For purposes of its paper trimming program, Ontario Hydro studied the situation, and although its figures are approximate, they give some idea of just how much paper a large corporation can use. Ontario Hydro spent $900,000 purchasing some 60 million sheets of paper during 1975 — or about 3,000 sheets per employee. One thousand sheets per person were created through photocopying. Over 9,000 mature trees had to be cut down to supply paper for Ontario Hydro that year.

The company also has 150 to 200 million pages of records. Even if one-third of these are ignored as being made up of books, manuals, catalogues and other necessary publications, the rest of the documents add up to a pile of paper nearly 39 times the height of the CN tower. The company is actively working to eliminate as much of this wastage as possible.

There are many ways to get rid of excess paper, but the most important thing to remember is to let employees know why you are trying to trim the paper load. Let them throw their own paper away; otherwise they will feel threatened.

Ontario Hydro sign for photocopiers

Try some of the following suggestions:

- Route memos rather than making copies for everyone. This will cut down on use of the photocopier as well as use of paper. The same principle applies to magazine articles and newspapers — route them rather than photocopying.
- Get people to look through their files and throw out any that are out-of-date or unnecessary. Studies show that companies never refer to

85% of their records while 95% of all references are to records under three years of age; and that 45% of filing equipment space is tied up in storing duplicate copies of dubious value. Fewer files mean less storage space and fewer filing cabinets.

- Recycle paper. Use scrap paper for rough drafts of letters, etc. What does it matter that the paper has been printed on one side? The federal Department of Energy, Mines and Resources has cut down on paper use by printing reports on the back of outdated maps.
- Reduce the number of photocopies made by having the person whose desk is closest to the photocopy machine keep tabs on its use; providing a key to restricted personnel to operate it; logging the number of copies; or using machine counters to keep track of copies.
- Photocopy and print on both sides of paper.
- Use alternatives to photocopying. If up to five copies are required, carbon copies are less expensive and ditto masters are recommended for more than five. However, it is not always easy to convince people of the merits of these two methods over the photocopier. In fact, factors such as difficulty of correcting errors on multiple copies can make use of carbon paper less productive, and depending on typing skill, a penalty due to high spoilage rates can result. However, for one or two copies it is always more economical to use carbons over photocopies.
- Sometimes it costs less to take chances rather than keeping records of costs down to the last penny. Marks and Spencer had a central inventory which listed the company's supplies in minute detail, down to the number of electric light bulbs at each store. But the company found that the cost of losses was less than the expense of this detailed control, and the inventory was abandoned. Take a look at your inventory system and decide whether the cost of perfection is too high.
- One branch of the same store further boosted morale by suggesting a saving on time clock cards. It abolished the clocks. Several stores followed suit, and after some weeks reported that punctuality had actually improved. Employees liked being trusted. And the company saved a million time cards per year.
- Use the phone rather than writing. Considering the cost of the average business letter, how many can be eliminated with a telephone call?
- Keep forms short and to the point. Not only will you save paper, but you'll save the time spent on filling out long, complex forms.
- Look into the micrographics field in which 280 pages, 15″ by 11″, can be reduced onto 14″ by 6″ fiche. Unless the document is legal and must be retained, its information on fiche is perfectly adequate, as well as easy to retrieve, cheap to produce, and cheap to store.
- Be careful with word processing equipment. While it can indeed produce letters, etc. at a lower unit price, it can also simply provide an excuse to produce more paper if it is not combined with a systematic review of paperwork.

Paper trimming programs may not look like big money or energy savers if you look at each sheet of paper individually, but the savings add up when the program is used by everyone in the office. And as well as providing money and energy savings, less paper usually means a more efficient office with time saved through less typing, reading and filing.

Purchasing with conservation in mind

The same principle that applies to paper also applies to office furniture and appliances. It takes energy to manufacture all these items, and every time something is thrown out, energy is wasted. When purchasing, keep this in mind. Buy products that are built to last. If old furniture is past its prime, consider refinishing or recovering it rather than throwing it out. It takes much less energy to refinish a desk than it does to build a new one. Take the old articles to second hand shops, or to the Salvation Army so that someone else can use them.

Companies can achieve savings by instituting a surplus equipment and furniture program — using in-house older pieces of furniture and equipment, thereby avoiding new purchases. For example, second hand office furniture can be used in plant areas where equipment is subject to abuse. Old typewriters can often prove useful in areas where the typing required is low in

volume. The amount of time required to co-ordinate such a program is small in comparison to the return realized.

When purchasing office equipment, keep energy in mind. Some photocopiers use less energy than others, for instance. If a requisition is received for an item that seems to constitute a waste of energy — be it an extra filing cabinet that will just house more paper, another electric typewriter or an air conditioning unit — make sure the extra energy use can be justified.

In short, be energy conscious about what you buy. The purchasing department is one place to stop growth of energy demand in the office.

The savings add up

Offices offer many energy-saving opportunities, and while many of the areas for saving may seem insignificant in themselves, they will add up to impressive energy savings.

In addition, many of the changes have beneficial side effects. Cutting down on paperwork can ease the burden on office employees and eliminate many routine and boring functions. Caulking windows may get rid of irritating drafts. Cutting down working hours to save on heating and lighting is a popular measure with many employees. And the doctors tell us that 68°F is a healthy temperature, and that using stairs instead of elevators is good for us.

Try some of the measures outlined in this booklet. If one company can save $1,700 per year by installing refrigerated drinking fountains, and another can save $5,000 a year by having the janitors clean during office hours — your company can make real savings too — without a major capital investment.

Tips on saving energy and money in office practices

Heating

1. Turn down the thermostat to 68°F during the day and 63°F during the night and on weekends.
2. Install a dual thermostat/timer system to activate a "night thermostat" on evenings and weekends.
3. Discourage use of space heaters by employees.
4. Encourage more casual, but warmer clothing.
5. Make sure the thermostats are located away from drafts or sources of heat.
6. Close drapes at night for extra insulation.
7. Install drapes lined with foil for insulation in winter.
8. When the winter sun is shining, open drapes and let solar heat supplement the heating system.
9. Make sure nothing is blocking sources of heat.
10. Consider removal of partitions to enable air to circulate freely in cases where they are keeping heat from some areas of the office.
11. If only some parts of the office are to be heated, use barriers to block off unheated areas.
12. Keep doors to unheated rooms and storage areas closed.
13. Consider installing zone controls if some areas of the office don't have to be heated.
14. Caulk windows and weatherstrip doors to keep the heat in.
15. Make sure the heating system is in good shape.

Cooling

16. Avoid use of air conditioning if possible.
17. Use fans since they require less energy.
18. Encourage employees to wear light clothing in summer.
19. Don't use appliances (photocopiers, electric typewriters) in summer unless you have to — they generate heat.
20. Turn out lights since they also generate heat.
21. Keep doors and windows closed during the hot part of the day if it's cooler inside, but open windows if there is a breeze.
22. Keep drapes closed during the day.
23. Use light drapes and blinds, awnings, sun screens, panels, overhangs or reflecting

windows to reduce solar heat.

24. If air conditioning is needed, make sure the unit is the right size for the office, i.e. the least amount of energy for the required amount of cooling. Check the Energy Efficiency Rating (EER).
25. Set air conditioners as high as possible without creating discomfort — 78 to 80°F.
26. Turn off the air conditioner and open windows during cool periods to save energy, but tell employees to keep windows closed when the air conditioner is on.
27. Make sure the air conditioner is well maintained.
28. Consider conversion to a "variable-air-volume" system, after obtaining advice from a consultant.

Ventilation

29. Check to see whether ventilation can be reduced, but consult local code authorities for approvals.
30. Install timers on ventilation fans.

Lighting

31. Turn off the lights, even when leaving for only a short time.
32. Install timers on lighting fixtures to shut them off on evenings and weekends.
33. Put signs on light switches reminding employees to turn them off.
34. Make sure light switches are highly visible.
35. Consider changing panel switching for large work areas to wall switching for smaller areas.
36. Look into "task" lighting.
37. Reduce security lighting on nights and weekends.
38. Use light finishes or colours on ceilings, walls, floors and furnishings to reflect light and reinforce the original light source.

Water

39. Heat water in washrooms only to 100°F, the minimum required for washing hands.
40. Boost the water temperature locally to provide hotter water for kitchens.
41. Consider installing a small heat exchanger in kitchens to preheat incoming water by using the heat of the dish water effluent.
42. Consider relocating water heaters so that they are as close to the point of use as possible.
43. Maintain the water supply system and repair leaks as soon as possible.
44. Regulate, repair or replace hot water controls that are not working properly.
45. Repair, replace or upgrade insulation on storage tanks if necessary.
46. Shut off domestic hot water circulating pumps during hours when the building is not occupied.
47. Install spray type faucets with flow restrictors or use spring activated hot water taps to control water use.
48. Consider replacement of free-running drinking fountains with spigot types that use a cup.
49. Use refrigerated drinking fountains to stop employees from wedging free-running drinking fountain handles in the "on" position to ensure cold water.
50. Cut down the number of flush cycles per hour on urinals.

Changing routines

51. Cut down the length of time required for lighting and heating by shortening office hours, e.g. changing hours from 8:30 to 5:00 to 8:30 to 4:30 by reducing the lunch hour from one hour to half an hour.
52. Encourage flexible working hours so that employees are not caught in rush hour traffic, and save gasoline travelling to and from the office.
53. Perform janitorial services during office hours, or schedule them earlier to save on heating and lighting.

Using office machines less

54. Shut off electric typewriters, photocopiers, adding machines, coffee pots, vending machines, water coolers etc. when not in use.

55. Don't purchase energy-hungry "frills" such as electric pencil sharpeners and staplers.

56. Discourage use of individual electric soup pots or kettles. Set up a central coffee depot or vending machine area instead.

57. Encourage use of stairs instead of elevators.

58. Reduce use of elevators after office hours.

59. Install demand devices whereby elevators answer calls only if a certain number of people need the service.

60. Fix elevators so that they go only to certain floors.

The paper jungle

61. Tell employees why you want to cut down on the amount of paper used, and let them throw their own paper away.

62. Route memos, magazines and newspapers rather than photocopying.

63. Throw out files that are out-of-date or unnecessary.

64. Use scrap paper for rough drafts of letters, etc.

65. Keep tabs on the photocopy machine.

66. Photocopy and print on both sides of paper.

67. Consider use of carbon copies and ditto masters as alternatives to photocopying.

68. Take a look at your inventory system and decide whether it is really saving you money.

69. Abolish time clock cards to save on paper and improve morale.

70. Use the phone rather than writing.

71. Keep forms short and to the point.

72. Look into micrographics for document storage.

73. Make sure that word processing equipment is not simply an excuse to produce more paper.

Purchasing

74. Buy products that are built to last.

75. Consider refinishing or recovering old furniture rather than throwing it out.

76. Take old articles to second hand shops or the Salvation Army; or use them in-house in areas where furniture is subject to abuse (e.g. plant areas).

77. Use old typewriters in areas where typing required is low in volume.

78. Keep energy conservation in mind when purchasing items such as photocopiers — some types consume more energy than others.

79. Question purchase requisitions for items that seem to constitute a waste of energy.

Conversion of office lighting saves 50% of energy

The situation: The Norquay Building in Winnipeg, a 10-story office block with 130,000 square feet of floor area, had a 14-year-old lighting system that had discoloured badly and provided poor, reduced lighting. Existing 15-square foot modules used two 40 watt RS fluorescent lamps and a PVC diffuser. Consumption in each module was 6.6 watts per square foot, giving a raw footcandle reading of 110.

Action taken: On a trial basis, a contractor installed a special vaulted ceiling with acoustic tile and one 40-watt RS fluorescent lamp per vault with a special injection moulded plexiglass lens. Consumption per module was only 3.6 watts per square foot with illumination reading increased to 120 footcandles. This design was subsequently modified for the rest of the building by using a slightly different acoustical vaulted ceiling and one 30-watt RS lamp per module with the same plexiglass lens. Consumption per module was 3 watts per square foot, giving a footcandle reading of 110.

Energy/dollar savings: Energy consumption and costs were cut in half right from the start since the new lighting system used only one fluorescent tube per ceiling vault instead of two.

Dollar savings: With energy prices at 1.5¢/Kwh and maintenance at 10¢/lamp/month, a cost appraisal reveals a saving of $30,000 per year for the entire building—enough to pay for the complete upgrading over a ten-year span. In addition, there were added benefits of improved visual environment, reduced glare and better acoustics.

Recommendation: If your lighting system is inefficient or antiquated, take a look at ways of improving it. The Norquay Building improvements were relatively expensive since changes were made to the ceiling as well as the lighting, but often changing the lenses in fluorescent fixtures can make a difference and may allow you to use fewer tubes.

Janitorial service performed during office hours

The situation: At a Detroit Diesel plant, janitorial service was scheduled to begin after the end of the office day shift — requiring office lights to be left on until 2 a.m. needlessly consuming energy.

Action taken:
Janitorial services are now performed during the office day shift so that lights can now be turned off at the end of the shift (from 5:30 p.m. until 6:30 a.m.)

Energy savings:

Previous consumption:

$$4200\,\text{kw} \times \frac{5375\,\text{hrs}}{\text{yr}} \times \frac{3413 \times 10^{-6}\,\text{MMBtu}}{\text{Kwh}} \times 66{,}100\,\frac{\text{MMBtu}}{\text{yr}}$$

Present consumption:

$$4200\,\text{kw} \times \frac{4440\,\text{hrs}}{\text{yr}} \times \frac{3413 \times 10^{-6}\,\text{MMBtu}}{\text{Kwh}} = 63{,}600\,\frac{\text{MMBtu}}{\text{yr}}$$

Savings: $66{,}100\text{-}63{,}600 = 2{,}500\,\frac{\text{MMBtu}}{\text{yr}}$

Cost of improvement: Nil.

Recommendation: Some, if not all, janitorial and other service functions presently carried out off shift should be carried out during a regular shift period. Benefits in terms of energy, and dollar, savings can be substantial.

Reduced ventilation reduces office heating load

The situation: An office in the northern part of the United States with 8,000 degree days, has an occupancy of 667 people and was supplied with 30 cfm/person of outside ventilation air for 40 hr/wk during the heating season. A consultant determined that this rate of ventilation could be reduced substantially in order to conserve energy in heating the building.

Action taken: Inflow of outside air was reduced of 8 cfm/person resulting in an overall ventilation rate reduction of (30-8) cfm/persons $\times$ 667 persons = 14,700 cfm.

Energy savings: Given an 8,000 degree days level, each 1,000 cfm of ventilation provided for 40 hr/wk requires 52.4 MMBtu heating energy per season (from table)

$$\text{Savings} = \frac{52.4\ \text{MMBtu}}{1000\ \text{cfm}} \times 14{,}700\ \text{cfm} = 770\ \text{MMBtu}$$

Dollar savings: 770 MMBtu/yr = 770 Mcf @ $2.00 = $1,540/year.

Cost of improvement: Nil.

Recommendation: Have a knowledgeable colleague or consultant determine present ventilation air rates, either from ventilating fan ratings or by measuring with an anemometer. These can then be checked against minimum required rates as established by codes for your business. Reductions in ventilation rates — and savings in energy are frequently possible.

Reduction in flush cycles conserves water

The situation: The energy conservation committee at Sangamo Limited's Toronto plant were as concerned with water savings as saving "energy". As a result, they saw the potential for significant savings in washroom water consumption, at no cost.

Action taken: By means of a simple adjustment to urinal dump valves in plant washrooms, flush cycles were cut from 42/hr to 20/hr with no effect on sanitary conditions.

Water/dollar savings: Estimated water savings during the first year of operation amounted to $1,800.

Cost of improvement: Nil.

Recommendation: No energy conservation program is too small. Reductions in water consumption in office and plant washrooms can be achieved by a number of means, including manual flushing for facilities and use of spring loaded faucets. These measures are low-cost and offer a high return on investment and a high "visibility" to employees.

Refrigerated water fountains save water

The situation: At the Woodstock, Ontario plant at Standard Tube of Canada Limited, 17 unrefrigerated water fountains represented a major waste of water resources. Workers in the plant wedged faucet handles in the "on" position to assure cold drinking water by continuous water flow. The fountains used a total of 780 gallons per hour and incurred a water cost of $1,800 per year.

Action taken: To obviate the need for continuously running water, the company installed 17 refrigerated coolers providing a very substantial water use saving — with a small offsetting cost for energy consumed in refrigeration.

Energy/dollar saving: No energy saving. A water savings equal to $1,700 per year is expected.

Cost of improvement: 17 coolers @ $350 = $5,950.

Recommendation: Give consideration to refrigerated water coolers as a means of saving water and at the same time improving employee morale and commitment to energy conservation. To make sure employees know that the coolers are actually saving money (and not just consuming greater amounts of energy), a small sign on the wall over the fountain might be appropriate.

Turning off lights at night and on weekends

The situation: Dominion Foundries and Steel (DOFASCO) has a 5 storey, 160,000 sq. ft. main office building located adjacent to its plant in Hamilton, Ontario.

Action taken: For a number of years, it has been the procedure to reduce lighting to about 5% between 10:30 p.m. and 6:30 a.m. and on weekends. The lights left on were for security. Recently, the company has also decided to reduce the security lighting and has wired out 3 of the 4 switches.

Energy savings: total savings due to turning out lights in off periods are about 3,000,000 Kwh per year.

Dollar savings: 3,000,000 Kwh/year × 2.5¢/Kwh = $75,000.

Recommendations: Reduction of lighting at night and on weekends, except for a few lights left on for security purposes can produce significant energy savings.

Window tinting cuts solar radiation gain

The situation: At the Hartford, Connecticut, head office building of the Phoenix Mutual Life Insurance Company, temperatures would reach 80—85°F on hot days because of its all-glass construction. With 1,050 people occupying 290,000 square feet of usable space, it was necessary to maintain more comfortable interior temperatures. Additional air-conditioning would have been "enormously expensive".

Action taken: Phoenix Mutual chose to apply a reflective sun-control film to the interior of all windows with southern and western exposure (a total of 22,700 sq. ft. of glass). The film chosen was a medium grade of silver-gray reflective film that transmits 33% of the sun's light.

Energy saved: It is estimated that the reflective film will reduce chilled water consumption for cooling by six percent or 5,000 tons per year.

Dollar savings: Not available.

Recommendation: Look toward reflective coatings as an alternative to installation of additional expensive air-conditioning.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg{\cdot}m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	1° = (π/180) rad
minute (of arc)	′	1′ = (π/10 800) rad
second (of arc)	″	1″ = (π/648 000) rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1 Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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SAVING MONEY THROUGH EMPLOYEE MOTIVATION AND PARTICIPATION

10

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SAVING MONEY THROUGH EMPLOYEE MOTIVATION AND PARTICIPATION 10

Saving money through Employee Motivation and Participation

Introduction:

In most of the booklets in this series, a good deal of stress is put on the need for automatic controls, timers and switches that will remove much of "the human factor" from day-to-day energy conservation.

This booklet emphasizes one major premise — that well-motivated employees are and always will be an essential ingredient in successful industrial energy conservation programs.

It deals with some of the broader issues involved and gives specific examples of the types of programs Canadian companies are undertaking to motivate and involve their employees in energy conservation.

People motivation — the key to a successful energy conservation program

The success of any energy conservation program depends largely on the extent to which people get involved. This means everyone — from top management to the worker on the production line.

Simply stated, there is little sense starting a program if management is not ready to endorse it wholeheartedly — with dollars as well as words. On the other hand, there is little point spending thousands of dollars re-insulating a plant if employees are not motivated to keep loading doors shut. And what good is turning down the heat, if uninspired or uninvolved employees bring in portable electric heaters which waste more energy than is saved?

Employees must be educated as to the reasons for energy conservation, and they must be involved personally in some way. Only if everyone in a plant "pulls together" will a program be truly meaningful and most effective.

The employee involvement must be a continuing one. If the conservation effort lets up, interest will wane. Old habits reappear and much of the ground gained is lost. It is easy to turn the thermostat back up — and there go the savings. If maintained by employees, heat recovery systems, temperature control valves and other mechanical systems will continue to generate savings, but casual waste will fluctuate with employee interest in, and commitment to, energy conservation in the plant.

As a simple rule: involve your employees in energy conservation and keep them involved!

A crucial element — support from the top

Employees can tell when a conservation effort is just tokenism — and one dead giveaway is a lack of highly visible support from the top.

Certainly, management support is a necessary part of any energy conservation program if people are to be properly motivated to achieve savings, and management support requires more than someone giving the nod to a conservation program and assuming the plant manager will just "fit this little job" into his busy schedule. Management participation means management that is committed to getting energy savings with the same intensity that it would place on extracting similar profits from increasing production.

An announcement concerning energy conservation should come from a company's senior executive early on in the program. He should make clear his commitment to conservation in some way — via the company newspaper, notices on all bulletin boards, or letters to employees. He should inform all employees that a program is being started, outline the reasons for it, name the committee and co-ordinator and outline the guidelines under which the committee is to operate. This top executive should show his continuing interest and concern by checking on progress

and accomplishments in the various departments, offering employees congratulations if results are good, and spurring them on to greater efforts.

When management is committed to a program, it constantly checks on progress and asks penetrating questions when results are not forthcoming. If there is a lack of co-operation between departments, explanations are required — nothing is allowed to drift. When a department is found to be slipping behind, obviously not meeting its goals, management can't wait another month to see if it will get back on track. The department that finds it has to explain its activity to management on a weekly basis soon realizes that a token performance is unacceptable.

The most powerful form of management support is example. 3M Company in St. Paul, Minnesota has one of the largest vanpool programs in the United States, and perhaps one of the reasons for its success is that some of the top managers ride to work in vanpools. When an employee sees a senior executive turn off the lights when he leaves the room for a few minutes, or take public transit to work, he will be reassured that there are no double standards — the program affects everyone!

Building a dynamic team

Once management support has been enlisted, the next step is to recruit a capable co-ordinator and a plant energy conservation committee.

Ideally, the program should be directed by a full-time person. If one employee can't be dedicated to the job, however, a hard-working individual who has energy conservation high on his list of priorities can still accomplish a great deal when given the support of top management.

The person who co-ordinates the program should provide vigour, initiative and enthusiasm. In addition, he should have technical ability and the ability to communicate with others. But the most important quality is enthusiasm — so others will be caught up in the spirit of saving energy. The co-ordinator also needs tact and must be able to work well in a team. Energy conservation can become a grinding and discouraging job, and it takes a high calibre individual to carry it through successfully.

Maintaining an Ongoing Program

To maintain continuing enthusiasm in the E.C. program, the following items should be included in the activities of the E.C. co-ordinator, or committee:

1. Hold regular meetings, perhaps monthly.
2. Involve members of all departments, so that they provide the communications link between the committee and plant personnel.
3. Institute and maintain a project and idea list for the plant(s).
4. Calculate energy use per unit of production. This should be done before E.C. is instituted and monitored while E.C. is in progress. Monthly calculations and records are recommended.
5. Attend seminars and participate in E.C. sessions outside the company.
6. Consider outside consultant services in special situations, if necessary.
7. Disseminate posters, booklets, tags, signs to remind plant personnel that E.C. is "in" in that plant.
8. Solicit employee participation in ideas. Some plants have a formal suggestion plan where the employee is rewarded for worthwhile contributions.
9. Publish energy related information to management and committee members in a monthly report, with progress relative to targets or goals set.
10. Publish energy related information periodically to employees by way of bulletins or magazines to inform them of progress and achievements in reducing energy use.

Company-wide representation

The energy conservation committee should have representatives from all parts of the company. Certainly, the plant engineering or plant facilities department must be represented, and it is often wise to choose the co-ordinator from this sector.

There are a number of benefits to having all departments represented on the committee. Essentially a problem-solving and action-taking group, the committee is also one of the most effective methods of selling the energy conservation program. Supervisors or department heads should be encouraged to participate in committee activities affecting their areas and assigned specific projects for investigation and follow-up.

Canadian General Electric's Davenport/Royce/Ward complex in Toronto makes the foreman the key figure in its program. In November, 1976, information sessions were held for more than fifty foremen and supervisors, as well as workshop sessions on how to involve plant people in the program. Each foreman develops a program for his area, including "rap" sessions with his people. The workshops were very rewarding, with the foremen pledging their leadership for energy conservation and a free flow of ideas. Among the ideas that emerged at the workshops were team competition between various areas and energy conservation tours around the plant to identify areas of wastage.

The work of the committee includes setting annual objectives in energy savings for each part of the company. It must communicate these objectives to the management in each part of the company and help with the organization of the various departments.

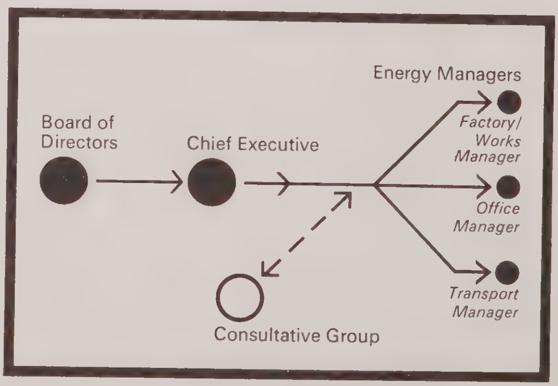
The chart at right shows how a progam could be set up — with support coming from the Board of Directors down through the Chief Executive for the program to representatives from different areas of the company. It is also worth considering the appointment of a specialist energy consultative group drawn from the company's own engineering expertise to provide technical guidance for the program.

The committee should seek support from other very important areas — either by including them in the committee or by seeking advice.

Urge the committee to work hard to obtain union support. Make energy conservation a joint responsibility, perhaps by forming management-labour committees to seek out ways of achieving economies. Most unions will overwhelmingly support energy conservation, particularly if the whole company seems to be committed. Many U.S. workers and their unions have seen devastating effects on employment due to unchecked energy shortages. While the Canadian situation is perceived to be different, Canadian unions are aware of, and share, enlightened citizens' concern for conservation.

The public relations or advertising people in your plant — if there are any — form another important group. Their job is communication, and they are the ones most familiar with the posters, pamphlets, newspaper articles and bulletins that will help tell the energy conservation story. Call on them.

Smaller companies are unlikely to have advertising or public relations staffs. Alternative methods of publicizing energy conservation, geared to a smaller firm, can be equally effective and easily handled by the program organizers. For example, employees could be given the opportunity to participate in a poster contest based on conservation themes in the plant in which they work. It doesn't have to be a professional effort; an amateurish one may be even more effective.



Motivating through measurement

Measurement is an important part of any energy conservation program. Goals must be set and savings documented if the success of the program can be judged.

To this end, an energy use survey or wasted energy audit should be conducted, department by department, at the beginning of the program and at periodic intervals thereafter. If done thoroughly, it will turn up areas where energy can be saved — through simple housekeeping practices, by retrofitting, or by conversion of systems — and give everyone an idea of where the inefficiencies lie. As time goes on, audits can be done at longer intervals. Some audits should be conducted at night or on weekends when the plant is not operating (see Guidebook for information regarding energy audits), but do not hide the fact that an audit is being conducted during working hours. Some of the provinces have an "energy bus" program whereby a team of experts arrive at the plant and perform a survey of energy use in the plant. Such energy audits are performed on request. If an "energy bus" is available in your province, make an employee "event" out of the initial visit — and publicize its findings.

Most effective energy conservation programs start out by aiming at one specific service — steam, compressed air, electricity — whichever offers the most significant potential improvement. When a specific area is chosen, let everyone know why it was chosen and give them some idea of the energy and dollar savings involved.

Sizable savings can often be achieved by postponing the need for new facilities or services. If the steam system is close to capacity, look at it first. You may derive a double benefit — the direct savings by reducing energy consumption and the indirect savings achieved by not having to invest additional dollars in equipment now. Again, let everyone know — tell them both that the energy conservation program will cut steam consumption by 10% and that this energy saving means you have been able to defer spending $700,000 on a new boiler for another year or so.

Both long-range and short-term goals should be set. It's good to set a target of 30% reduction in energy consumption over three or four years — it provides a continuing incentive — but from the point of view of employee motivation, a shorter attention span is needed. A short-term target of, say four or five percent savings in six months, is something employees can try to meet. The satisfaction of seeing themselves approach and meet short-term goals can be a real "kick" for employees.

Monitor your energy savings

Given the commitment and managerial organization, the next step is to determine your company's energy requirements. This is crucial in:

- —assessing the steps needed to save energy
- —measuring the success of the energy-saving program.

Do you know your energy consumption for the various stages of individual processes? Monitor the energy used in each process and keep good records. Then check that savings are being made. Records should be:

- —kept as simple as possible
- —related to each step in the process
- —maintained for constant time periods (e.g. monthly moving averages on an annual basis).

They should record the:

- —form of energy and total consumption (expressed in the most convenient accounting units)
- —total production associated with total energy consumption
- —specific energy consumption associated with specific production, output or performance.

Cost and management accounts may well help to provide much of the basic information needed. The results will help you to:

- —establish what you are spending on energy
- —identify areas where savings can be made.

All goals should be set in familiar units that all workers will recognize. If they work with and are familiar with pounds of steam per 1,000 pounds of product, use that as a measure. If it is required, transfer the numbers into gallons of automotive gasoline, dollars — as long as it is a unit employees will accept.

Regular reports are another way of keeping employees involved. An analysis of each department's performance should be prepared and presented to management showing current performance, progress to date, and the program's targets. Install meters where possible to measure department energy consumption — or regularly monitor progress and record it on a form such as that used by Bell Canada or 3M (see example). If employees know the company is keeping such strict tabs on their work, they are likely to pay more attention to energy conservation.

The rivalry incentive

These reports guide the energy conservation committee in developing the program and they can also generate a little healthy rivalry. Combined reports showing how each section is doing can be circulated throughout the plant. This shows each section its progress and allows comparisons in relation to other sections. Nobody likes to be last, so this type of report can be a valuable incentive to improve poor performance.

Reports on the performance of other divisions or plants within the same company can also create some friendly competition. In one chemical plant, the goal was a 30% decrease in steam usage, to be achieved within three years. The target was based on having enough steam for a new chemical plant without adding extra boilers to the existing plant. If the 30% reduction was made, that branch of the company would get the new plant; if it wasn't, another branch of the company would get the big expansion. Rivalry with the other plant was a big incentive for reducing energy consumption. Even if this approach does not conform with the management policy at your company, the "rivalry" motive is sound.

There are many other ways to involve employees, but John Deere's Welland, Ontario Works employs a unique method — specifically assigning an hourly employee to energy conservation maintenance and energy audit recording. The employee chosen is a third or fourth class stationary engineer. During the first year of the John Deere program, a 23% saving was achieved, exceeding the corporate goal of 20% by 3%. The following year, the stationary engineer was transferred with no replacement. Without any centralized energy conservation maintenance program, the savings dropped to 19%, 6% short of the corporate goal of 25%. The program has now been reinstated.

Meters have psychological impact

The physical installation of measuring devices can have a beneficial psychological effect on a department. The fact that consumption is being measured is often enough to cause large load reductions. Besides, without accurate measurement, the performance of a particular piece of equipment or department can not be evaluated. A rule of thumb might be to put in a meter when the annual cost of the service represents five times the cost of the meter. A saving of 20% of one year's consumption will pay for the meter and leave the facilities for continuing to accurately measure and control energy consumption in the area.

Again, the important message is — communicate! Measurement provides employees with a solid indication of their progress and gives them an incentive to work harder — but only if the results are made known.

Involving all employees

Employees are the backbone of the conservation program. They turn off hot water taps and unnecessary lights and shut off production machinery when not in use, and their participation is not limited to simple housekeeping measures, though these are the ones that depend most on employee action. Whether the company is retrofitting or converting a whole system, conservation savings are ultimately dependent on the employees' personal contributions. Employees are the ones who will run new machinery efficiently — and they should be given training on how to do just that. Even if a company makes big changes to its steam or compressed air systems,

energy savings will be small if employees are not educated on how to work with those systems. And there is little sense fitting a loading dock with air-tight doors, if employees are not taught to keep those doors shut when not in use.

Employees must be involved, informed and motivated in all aspects of the conservation program if maximum savings are to be achieved. Once they are told about the program, and shown examples of waste and poor practice, they can be invaluable. Where lights are turned off automatically or where machinery shuts off at a certain time each day, employee help is less essential. But in the final analysis, there is really no substitute for an enthusiastic worker who understands the need for, and supports, plant energy conservation programs.

Motivating people for energy conservation means coming to grips with a couple of frequently encountered employee attitudes. First, many employees in Canadian companies find it hard to believe there is an energy crisis. Fuel shortages and layoffs due to fuel shortages are things that happen in the United States, not here.

The other attitude is apathy — "What can my efforts do to reduce energy consumption?" If an employee believes that any efforts to turn out the lights and turn down the thermostat are futile, he will not be very enthusiastic about the company program.

There are several ways to tackle these feelings. Energy conservation is something that is easy to relate to if it is "handled" properly, and the employees must be made aware of ways in which it relates to them.

Explain that fuel shortages will happen in Canada. Show them government projections that show an energy shortfall in the early-to-mid 1980s unless something is done to conserve energy — now! Explain what this will mean in terms of job security. This is a "negative" motivator, but in the right context, it is one of a number of ways to get the message across.

Explain what energy conservation means for the company; that Canadian firms must compete in international markets and unless we are thrifty with our energy, the competition is even tougher. Again, this means loss of employment. Better still, explain that if energy thrift is practised, *more* jobs can often be created.

Stress the dollar savings. This "bottom line" approach may or may not have a major impact, depending on the size of the company, the state of employee relations, existence of profit sharing, and the many other factors which affect loyalty to the company.

Stress participation

One of the best appeals is to stress the employee's crucial role in energy conservation. Tell him why the program can not function without him. Make him accountable for some area of the program, however small. Appeal to his pride and sense of responsibility.

Use a little psychology. People do not like to be told their old practices were inadequate; instead stress the future and the need to adapt to a new, evolving society based on conservation rather than consumption. Relate this to home heating bills and car gas mileage. After all, you are really asking the employee to help you get more "miles per gallon" out of your plant equipment.

One of the best ways to change the images is by example — by having managers participate in the program to show that conservation does not detract from status. Show the inconsistencies between excessive energy consumption and values held by employees. Such a message might refer to a person's love of the great outdoors, and then show how excessive use of electricity creates a need for new sources of power which can destroy parts of that wilderness.

The human touch

Be human. Anticipate the problems that will come up and suggest ways to cope with them. For example, if the thermostat is lowered to 68 degrees Fahrenheit, people frequently feel cold, especially at first. Often, the natural reaction has been to bring space heaters into the office. Explain that such heaters use up a great deal of energy, and suggest that employees wear sweaters.

Do not just unilaterally take out light fixtures, or people are bound to notice and complain. Explain why you are taking the fixtures out, and how you determined that the lighting levels would still be adequate. Make sure light switches are not hidden — if you want people to participate

in the program, show them where the switches are, and if they are in very awkward locations, move them.

Don't be afraid to use humour in your energy conservation program, since the light touch is sometimes the most effective way of getting the point across. That is why editorial cartoons are a staple part of most major newspapers. Some examples of humour used effectively include the federal government's "Garbage Gus" used to encourage consumers to throw out less and conserve energy; and the Etobicoke, Ontario Board of Education's program aimed at school children which uses the cartoon character, "Billy Bulb".

Make sure, however, that the approach taken does not appear to insult the intelligence of your employees.

Since energy conservation involves an attitude change, it is a good idea to send publicity material to the place where many attitudes originate — the home. Sometimes children can put pressure on the parents to develop good energy conservation habits, and sending information home encourages the employee to practice energy thrift in all areas of his life. Why not send a special energy conservation issue of the employee bulletin to the home, stressing the merits of the company program. Stuff memos regarding energy conservation into pay cheque envelopes. Send Office of Energy Conservation booklets to the home — "100 Ways to Save Energy and Money in the Home", "The Billpayer's Guide to Furnace Servicing", and "The Garbage Book". If an employee practices energy conservation at home, he is more likely to do it in the plant.

Publicizing Energy Conservation

One of the most effective ways of selling the energy conservation program is a continuing publicity program designed to reach the workman on the job. Such a program should explain your goals, inform people about the cost of losses and point out where major savings and improvements have been made, but above all, it should make the program visible. Think of successful safety programs in which stickers are placed on machines, posters put up on plant walls and tips provided in company newsletters, and follow the lead. The energy conservation committee should use all these publicity

Bell Canada tent card gets the message across

methods to make the program known.

Among the ways of publicizing an energy conservation program are:

- A rack of pamphlets in the lunch room or the lobby.
- Tent cards. Bell Canada has used this system. The cards had six different slogans and each slogan was displayed for a two-week period. They were used mainly on company cafeteria tables, but also in reception areas and on office desks.
- Signs and posters around the plant or office.
- Progress charts showing targets and achievements.
- Signs or stickers over taps and lights. One popular type of sticker can be fitted over a light switch.
- Pictures on bulletin boards. This is one of the simplest and least expensive publicity

methods, but it can work well. A picture of a steam leak posted on a bulletin board can be a very effective way of ensuring that future problems of that nature are dealt with quickly.

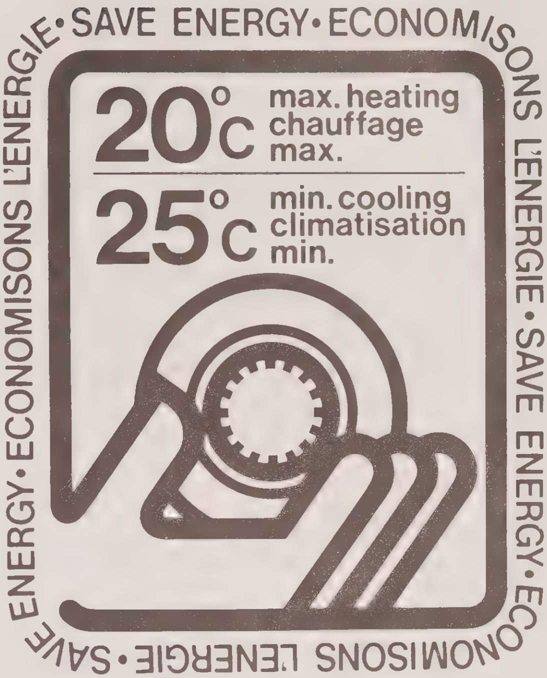
- Feature items in the company "house organ". One special issue can be devoted to energy conservation, or a series of articles could explain the program. A suggested format for an energy conservation program in the company's newsletter includes the following articles:

1. the president's announcement of the energy conservation program and explanation of the reasons
2. the formation of the energy conservation committee
3. the targets set for the company
4. reports on specific programs as they are carried out
5. soliciting conservation ideas from employees followed later by an article detailing some of these ideas
6. an article regarding the way in which actual savings stack up against the targets.

- Letters and memos from the company's top executive and the program co-ordinator. These are a must. There should be a letter to all employees announcing the program and follow-up letters regarding progress. Some companies make their memos a detailed information package to be sent out to all employees including: the aims of the program; the names of conservation committee members; a brief description of the Canadian energy situation; a description of main energy conservation measures and anticipated savings; and a checklist of conservation measures.

- Contests. These can take many forms — logo contests, slogan contests or contests between departments or divisions of a plant. Some companies already have employee suggestion plans, in which employees are reimbursed for suggestions on the basis of how much money the suggestion will save the company. By setting up a conservation suggestion plan, or including conservation suggestions in the existing plan, employees can be effectively involved.

Sample sticker from Federal Government Program



- Incentive plans. Shell Canada had a week-long program in late 1976 in which five dollars was given to an employee's favourite charity if he complied with any one of a list of conservation measures during that week. This type of program — with lower dollar incentives, perhaps — could be useful on a continuing basis. Other incentives include reduction of parking lot fees for carpoolers or contribution of money toward public transit fares.

Employee education

There is much to be gained by formally educating employees as to the reasons for energy conservation. Distribute books to employees. Send selected employees to seminars. Hold in-plant workshops.

Some companies have set up energy conservation training programs for department heads; and others have included energy conservation in existing training programs.

Shell Canada has focused on one area of education, by setting up a computer simulation of a refinery process furnace to help train process operators and supervisory personnel.

The theory is that by learning more about the variables of efficient furnace operation, the employees will save the company energy and money. Results have been encouraging so far, and benefits include more rapid re-establishment of optimum furnace efficiency following a major process change or plant upset, and improved ability to make furnace adjustments which result in higher furnace efficiencies. The program has proven worthwhile, and Shell estimates that even a 1 percent improvement in furnace efficiency would provide savings of over 50,000 barrels of fuel per year, or $400,000 at current fuel prices.

While smaller plants can't hope to achieve savings of that magnitude, the principle is the same — by training the people that operate the machine, you can save money since that machine will be operated more efficiently.

Making conservation second nature

With costs of all types of energy on a seemingly straight line increase, conservation is a necessity. Educating people to close doors, turn off lights and spot energy waste is critical — from the point of view of the company and of society as a whole. Without being overly dramatic, energy conservation must become a way of life and Canadian industry has a role to play in helping this to happen.

Involving people in energy conservation means changing habits. Top managers must be willing to participate in the program, even when it means slight changes in their lifestyles. All employees must learn to practise energy thrift in all areas of their daily routines.

Motivating people for energy conservation is a difficult task. Many people do have preconceived notions about energy — "There is no shortage in Canada" or "My efforts will make no difference to overall energy consumption".

But with management support . . . a dynamic team headed by an enthusiastic co-ordinator . . . measurement and reporting of results . . . and continuing publicity and education programs, the job can be done . . . and done well.

Motivate your employees. It is the key to a successful energy conservation program.

Tips on employee motivation and participation

Support from the Top

1. Enlist management support — management participation means management that is committed to getting energy savings with the same intensity that it would place on extracting similar profits from increasing production.
2. Have a senior company executive make an announcement concerning energy conservation early on in the program.
3. Management should check on the progress of the program and ask penetrating questions when results are not forthcoming.
4. Management should support the program by example — make sure there are no double standards!

Building a dynamic team

5. Recruit a capable co-ordinator and a plant energy conservation committee.
6. If possible, enlist a full-time person to direct the program.
7. Choose a co-ordinator who has enthusiasm, tact, technical ability and the ability to communicate with others.
8. Make sure representatives come from all parts of the company and be certain the plant engineering or plant facilities department is represented.
9. Encourage supervisors or department heads to participate in committee activities affecting their areas and assign them specific projects for investigation and follow-up.
10. Hold workshop sessions on how to involve plant people.
11. The committee should set annual objectives in energy savings for each part of the company, communicate these objectives to management and help organize the various departments.
12. Urge the committee to work hard to obtain union support.
13. Enlist the support of public relations and advertising people in the company — if there are such people.

14. In smaller companies with no public relations or advertising staffs, alternatives such as poster contests can be effective.

Motivating through measurement

15. Conduct an energy use survey, department by department, at the beginning of the program and at intervals thereafter.
16. Conduct some audits at night or on weekends since some inefficiencies can best be seen at these times.
17. Make an employee occasion out of a visit by the Energy Bus, if there is one in your province.
18. Start by aiming the program at one specific service — whichever offers the most significant potential improvement.
19. Make use of programs which will postpone the need for new facilities or services.
20. Set both long-range and short-term goals.
21. Set goals in familiar units that all workers will recognize.
22. Make regular reports on each department's performance.
23. Use the rivalry incentive — e.g. reports on the performance of other divisions or plants within the same company can create healthy competition.
24. Assign one employee to energy conservation maintenance and energy audit recording.
25. Install measuring devices to provide employees with a solid indication of their progress and give them an incentive to work harder.

Involving all employees

26. Come to grips with two frequently encountered employee attitudes: "Is there really an energy crisis?" and "What can my efforts do to reduce energy consumption?"

- Show them projections of an energy shortfall.
- Explain what energy conservation means for the company.
- Stress the dollar savings.

27. Stress the employee's crucial role in energy conservation.
28. Portray a new, evolving society based on conservation rather than consumption.
29. Show that energy conservation does not detract from status.
30. Show inconsistencies between excessive energy consumption and values held by employees.

Publicizing energy conservation

31. Make the energy conservation program highly visible by placing stickers on machines and posters on plant walls.
32. Put a rack of pamphlets in the lunch room or lobby.
33. Use tent cards on cafeteria tables, reception areas and on office desks.
34. Put signs and posters around the plant or office.
35. Make progress charts showing targets and achievements.
36. Put signs or stickers over taps and lights.
37. Use photographs on bulletin boards showing problem areas.
38. Write feature items for the company "house organ".
39. Circulate letters and memos from the company's top executive and the program co-ordinator.
40. Hold contests — logo contests, slogan contests or contests between departments or divisions of a plant.
41. Set up a suggestion box for energy conservation ideas.
42. Use incentives to encourage energy conservation.

Employee education

43. Distribute books on energy conservation to employees.
44. Send selected employees to seminars on energy conservation.
45. Set up energy conservation training programs for department heads or include energy conservation in existing training programs.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

(Conversion factors shown in bold face type are exact)

Approximate Common Equivalents	Accurate Conversions
1 in. = 25 mm	in. x **25.4** = mm
1 ft. = 0.30 m	ft. x **0.3048** = m
1 yard = 0.91 m	yd. x **0.9144** = m
1 mile = 1.6 km	miles x **1.609 344** = km
1 sq. in. = 6.5 cm^2	sq. in. x **6.4516** = cm^2
1 sq. ft. = 0.09 m^2	sq. ft. x **0.092 903 04** = m^2
1 sq. yd. = 0.84 m^2	sq. yd. x 0.836 127 4 = m^2
1 acre = 0.40 ha	acres x 0.404 685 6 = ha
1 cu. in. = 16 cm^3	cu. in. x **16.387 064** = cm^3
1 cu. ft. = 28 dm^3	cu. ft. x 28.316 85 = dm^3
1 cu. yd. = 0.76 m^3	cu. yd. x 0.764 555 = m^3
1 quart (lq) = 1.1 ℓ	quart (lq) x 1.136 522 = ℓ
1 gallon = 4.5 ℓ	gallon x **4.546 09** = ℓ
1 oz. (Avdp.) = 28 g	oz. (Avdp.) x 28.349 523 = g
1 lb. (Avdp.) = 0.45 kg	lb. (Avdp.) x **0.453 592 37** = kg
1 hp (UK) = 0.75 kW	hp (UK) x 0.7457 = kW
1 lbf. = 4.4 N	lbf. x 4.448 222 = N
1 psi = 6.9 kPa	psi x 6.894 757 = kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Luminance	candela per square metre	cd/m^2
Molar entropy	joule per mole kelvin	J/(mol·K)

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1° = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\ 800)$ rad
second (of arc)	″	$1'' = (\pi/648\ 000)$ rad
litre	l or ℓ	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg = 1000 kg
ångström	Å	1Å = 0.1 nm = 10^{-10} m
bar	bar	1 bar = 100 kPa
hectare	ha	1 ha = 10 000 m^2

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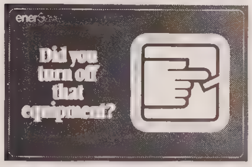
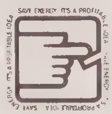
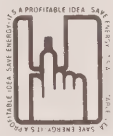
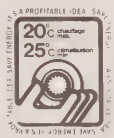
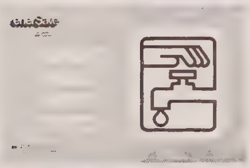
	______		______
	______		______
	______		______
	______		______
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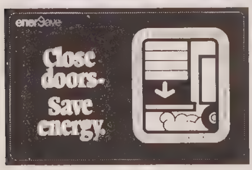	______		______

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